AUSTRALIAN NATURE STUDIES

An Australian Crimson Parrot.

Australian Nature Studies

A BOOK OF REFERENCE FOR THOSE INTERESTED IN NATURE-STUDY

By

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PREFACE.

In presenting *Australian Nature Studies,* the result of several years of work in my limited leisure time, the author hopes that the non-expert, the nature-lover, the teacher, the scout-master and others interested in boys and girls will find such direction and assistance as will enable them to see and understand enough of nature about them to lay the foundations of the observing habit. The expert and those who become interested in special branches will follow their interests and proceed to use the scientific text-books now readily obtainable.

As the book was written with a view to helping those interested in the education of the young, technical terms have been avoided, for there is no room for such in the nature-study of children under 12 years of age.

For the convenience and assistance of students and teachers, not yet expert in grouping new knowledge in nature-study, each section has been made, as far as possible, complete in itself. This method of treatment has necessitated some repetition of diagram and matter. Many common things are treated and some rare ones of special interest met with in our work in nature-study.

My thanks are due to scientists, naturalists and friends who kindly assisted with criticism, suggestions, proof-reading, and specimens and photographs for the illustrations. Especially am I indebted to Sir Baldwin Spencer and Dr. G. Sweet (Biology Department, University of Melbourne), Professor Ewart and Dr. Ethel McLennan (Botany Department), Messrs. J. A. Kershaw, F.E.S., F. Chapman, A.L.S., and J. F. Spry (National Museum); Mr.

D. Le Souef, C.M.Z.S. (Zoological Gardens); Mr. Cronin (Botanic Gardens); Messrs. W. Laidlaw, B.Sc. (Government Biologist), C. French, junr. (Government Entomologist) and C. Brittlebank (Plant Pathologist); Major H. W. Wilson, O.B.E., B.Sc. (Chemical Adviser, A.I.F.); Mr. W. B. Alexander, M.A. (Advisory Council of Science); Mr. J. Searle (Field Naturalists' Club); Mr. R. W. Armitage, M.Sc., F.G.S.; J. H. Betheras, M.A. (Assistant Chief Inspector, Education Department), C. J. Gabriel (Field Naturalists' Club), and Mr. P. J. Sharman, M.Sc., and Miss Keartland, M.Sc. (Teachers' College). Miss G. M. Cheney, B.A. (Education Department) rendered valuable assistance with the illustrations.

Mr. A. T. Mockridge, late Flying Corps, A.I.F., who devoted much painstaking work to the numerous original drawings, merits my special thanks. When the war prevented publication of this book, he converted the proposed outline diagrams into the numerous high-class illustrations we were fortunate in securing. When the call became more insistent, he enlisted, completed the drawings, and left for the front with the Flying Corps.

Free use has been made of available literature in Natural History, Zoology, Botany, Geology, Physiography, and Nature-study. Want of space prevents acknowledgment through the volume. I am specially indebted to *The Natural History of Plants* (Kerner and Oliver); *Matriculation Botany* (Ewart); *Lessons with Plants* (Bailey); *Textbook of Zoology* (Parker and Haswell); *Textbook of Botany* (Strasburger); *Australian Insects* (Froggatt); *Insects,* Cambridge Natural History Series (Sharpe); *Destructive Insects of Victoria* (French); *Victorian Butterflies* (Anderson and Spry); *Manual of Nature-Study* (Mrs. Comstock); *Nature Study and Life* (Hodge), and *The Nature-study Idea* (Bailey).

To the council of the Royal Australasian Ornithologists' Union my thanks are due for special permission to use five plates depicting Australian birds in natural colors. To that distinguished patron of Australian nature-study—Mr. H. L. White, of Belltrees, Scone, N.S.W.—I am

indebted for the plate of the handsome Blue Wren. Five of the colored plates are from three-color photographs taken direct from the bird, a branch of nature photography in which Australia leads.

Above all, I must acknowledge my indebtedness to the Director of Education, Mr. F. Tate, C.M.G., M.A., I.S.O. He was far-sighted enough to recognize the value of nature-study when it was a new subject and was described as a "frill" or "fad." He assisted in the direction and development of that subject on the free open-air lines that have proved so effective. Further, he has assisted with suggestions and criticisms.

Abundant illustrations, cross references in the letterpress to diagrams, and an extensive index will enable readers to follow a subject under different headings.

A discussion of the aims, principles and methods of nature-study and practical suggestions for carrying on nature-study under school conditions are given in the appendix.

Suggestive topics for each class for each week of an eight-years' course of nature-study—a matter of moment to those directing the nature-study of the young—are given on pages 480-483.

Having had unusual opportunities and experience in nature-study as teacher, lecturer, organizer and inspector, in addition to a wide field acquaintance with the Australian fauna, flora, and natural features, the author offers this volume as an Australian contribution toward the development of a subject that has assisted in bringing reality into schools and interest into the lives of many children as well as adults

A considerable reduction in space with little reduction in the scope of the work has caused much compression of the letterpress and some crowding of the illustrations. I trust, despite this, the work will help many to a closer acquaintance with nature in some of its varied aspects.

J.A.L.

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AUSTRALIAN NATURE STUDIES.

PART I.

PLANT LIFE.

Much of our work in nature-study is based on living things—plants (Part I.) and animals (Part II.). Some is based on inanimate nature; this, with Pond Life, is treated under General Studies (Part III.).

The life-history of the pea plant has been followed as an introduction to the study of Plant Life. Each stage—seed, developing plantlet, leaf, root, stem, flower, and fruit—serves as an introduction to a more general study of that phase of plant life.

As far as convenient the work is illustrated by simple experiments with home-made apparatus; these may be readily performed for himself by the nature-student.

This study serves to introduce a subject to the inquirer, to reveal something of interest in a common object, and to let him know *how to see and when he is seeing.* If interested, he applies the knowledge and power and develops a habit of observing independently. Our goal, then, is not the acquisition and memorizing of the facts, but the habit of seeing and thinking for oneself.

Great pressure on space consequent on the considerable reduction of the number of pages has necessitated often the close packing of the figures on the plates and the reduction of the descriptive letterpress to a minimum.

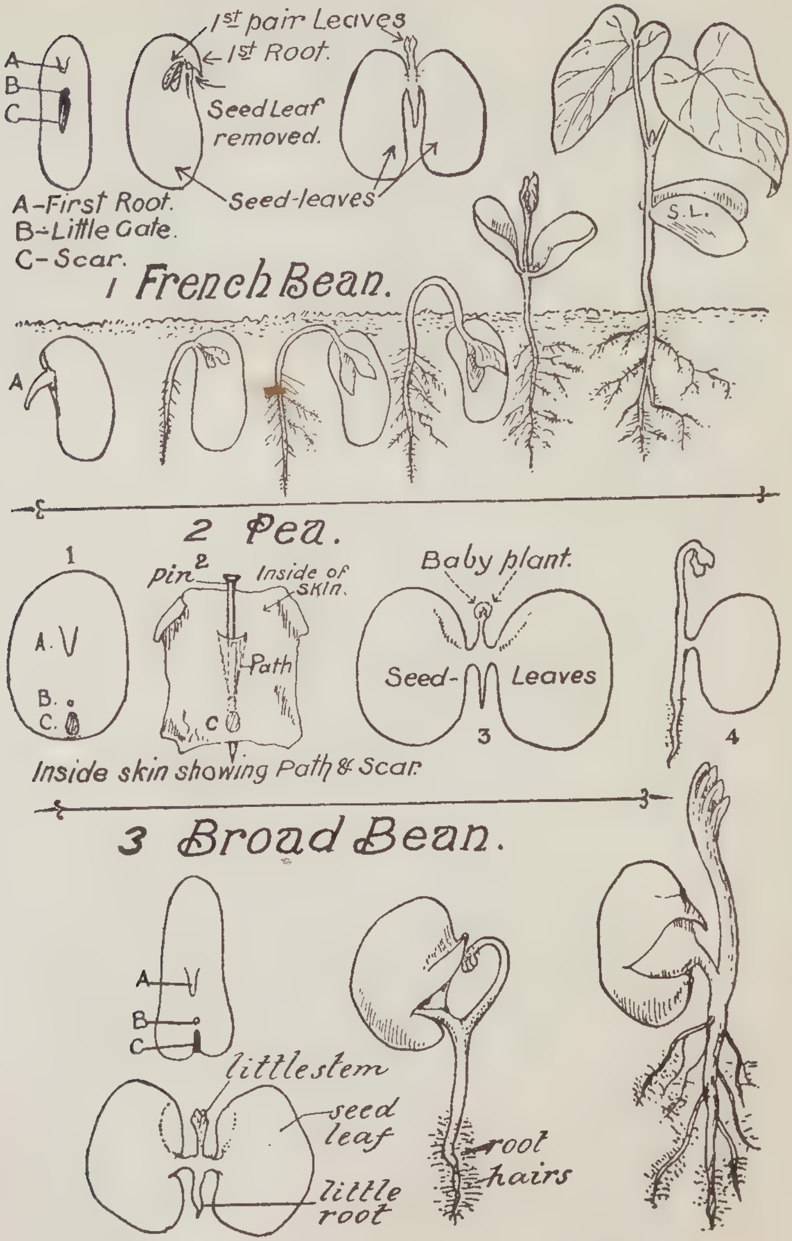

PLATE 1.—GERMINATION STUDIES.

1, French Bean; 2, Pea; 3, Broad Bean.

For (1:2) in the letterpress read "see plate 1, figure 2"; the number before the colon refers to the plate; the number or numbers after the colon, to the figure on that plate.

CHAPTER I.

SEEDS AND THEIR DEVELOPMENT.

A. The Pea—A Common Seed.

Supply each child with a garden pea that has been soaked in water about twenty-four hours. Have in the room peas developing on damp wadding, sand, or sawdust for different lengths of time up to a fortnight.

"If[1] this pea were planted, what might be seen after a few weeks?" "A pea plant." "Where did the plant come from?" "From the pea seed." "Is there a plant in the seed now?" Most children think "no"; a few think "yes"; still fewer suspend judgment until they look inside the pea. Presently we shall open the pea, and then we shall know.

Before doing that, we must examine the outside. Draw[2] one side on a blackboad or in a sketch book (1 : 2[1]) showing the "little root" and the "scar." Names must now be obtained for these. "Who can shell peas?" "What held the pea in place?" "A stalk." "What is this mark?" "The mark left by the stalk of the pea." Examine a fresh pea-pod to confirm this. Do not accept or reject answers; always refer, if possible, to the thing itself for confirmation. "What do you call a mark left by a burn or cut?" "A scar." Label it, the "scar." "What does the pointed part become?" Discover on developing plants that it becomes the root; label it the "little root."

The problem is, "How does the 'little root' get through the tough skin?" With the thumb-nail cut the leathery seed-coat (1 : 2) half-way round on the side away from the little root, and take it off. "How can the root get out?" Various answers are given. "The skin cracks." "If that

[1]As an indication of method of treatment, questions and partial answers have been given in this study. Our purpose is not the acquisition of the facts, but the leading of the child to see and think.

[2]Drawing is the universal language: a simple fully labelled drawing is usually the best description: it involves correct seeing and understanding.

was right, it would do. But what if it cracked at the wrong time, in the wrong place, or forgot to crack? It cannot be left to chance. Try again." "The water made the root swell; and it burst the skin." "Good answer, think of that. Put a boy in a cardboard box. What would happen?" "The boy would burst the box." "Yes; could he burst an iron box?" "No." "The skin is too strong, it cannot be burst." "The water makes the skin rot and the root gets out." "Which would rot first, the fleshy inside or the leathery skin?" "The fleshy inside." "If the root cannot get out, what will happen?" "It will die." "It does not die. How is it to get out of the seed?" "It bores its way out." "How do you bore a hole?" "With a brace and bit or a gimlet." "How, then, can the little root get out?" The children cannot suggest further; they have found a problem in the pea.

Pains should be taken to exhaust every plan suggested. When children cannot suggest further, they appreciate the *wonder* of the matter. If they are told at first, they are deprived of the exercise of thinking, and the wonder element is lost; provision for the emerging root is to be expected.

"Let us think of something else. Where does a chick come from?" "From an egg." "How does it get out of the egg?" "The shell cracks." Deal with this as before. "The mother pecks a hole in the shell." "What about eggs in an incubator?"

At last, a child may say, "The chick pecks its way out." "How do you know?" "I heard one tapping at the shell." Then tell of the remarkable "egg-tooth" on the beak to enable the chick to break the shell; for, once the shell is chipped, the chick easily bursts it. Has the little root a hard piece with which to knock a hole in the leathery skin?" "No." No further suggestions. We must see if the mother plant provided means for the root to leave the seed. Soon someone sees, on close examination, a small hole (1:2[1]) between the scar and the little root. Give each child another soaked pea. Wipe the outside and squeeze the pea gently. Water comes from the hole. I remember the excitement of a first grade boy when he discovered this hole. He startled the class by calling out, "There is a hole in mine"; others soon found it. Label the "little gate" on the drawing. Make sure all see it. (*The little gate serves primarily for the*

entry of the pollen tube. To allow for the emergence of the "little root," the skin above the little gate is thin. The point is that provision is made for the emergence of the root.) Peas soaked for two days show the emerging "little root." "How can you find the gate at home?" "Look for it." "How does the little root find the gate?" "Has it eyes?" "No." "How can you find a gate in the dark?" "Follow the path." "I wonder how the little root finds the gate." "Perhaps there is a path." The children smile incredulously. To have a gate is wonderful, but a path is surely beyond a common pea. "We are now ready to open the pea to discover, first, if there is a path leading to the little gate; secondly, if there is a 'baby plant' inside." With the thumbnail or other suitable implement cut through the skin along the side away from the little root. The skin of a damp pea cuts easily. Press the skin up on one side and then on the other, and it slips off readily. Look carefully when removing it from the root. The children are surprised to see the root in a little pocket (1 : 2); it cannot lose its way. To have a "gate" is wonderful, but such a "path" is marvellous. The path is connected primarily with pollination; it serves secondarily to direct the emerging root.

Having seen the "little gate" with its wonderful "path," look for the "baby plant." Press the two large masses apart gently; look in between. "Who sees anything?" Hands fly up. All see the little root ($1 : 2^3$) pointing down, the curved tip between the seed leaves, and a central part to which the seed leaves, curved tip, and little root are attached. Label the "baby plant." Remove one seed leaf. Draw the half with the "baby plant" on it. Examine growing peas to discover that the curved tip becomes the stem. Label it "little stem." "Who thinks there is a baby plant in the pea?" Every hand is up. "How do you know there is one?" "Because I can see it." That is the best of all reasons. "What are the two large bodies for?" "To protect the baby plant." "Yes, for anything else?" No answer, perhaps. "Think again of the chick. How old is a chick on leaving the egg?" "One second—one minute—an hour—a day—three weeks." "Yes! The chick grew for three weeks in the egg. What did it live on?" "Nothing—the 'white'—the 'yolk'." The yolk is the chief food; the white helps.

By examining germinating French bean (1), sunflower (2: 1), and cabbage seeds, the children see that the two masses in a pea correspond to the first leaves on the sunflower, French bean, and cabbage plants. Hence we can call them "seed leaves." "As they contain food, do they get larger or smaller as the plant grows?" "Smaller."

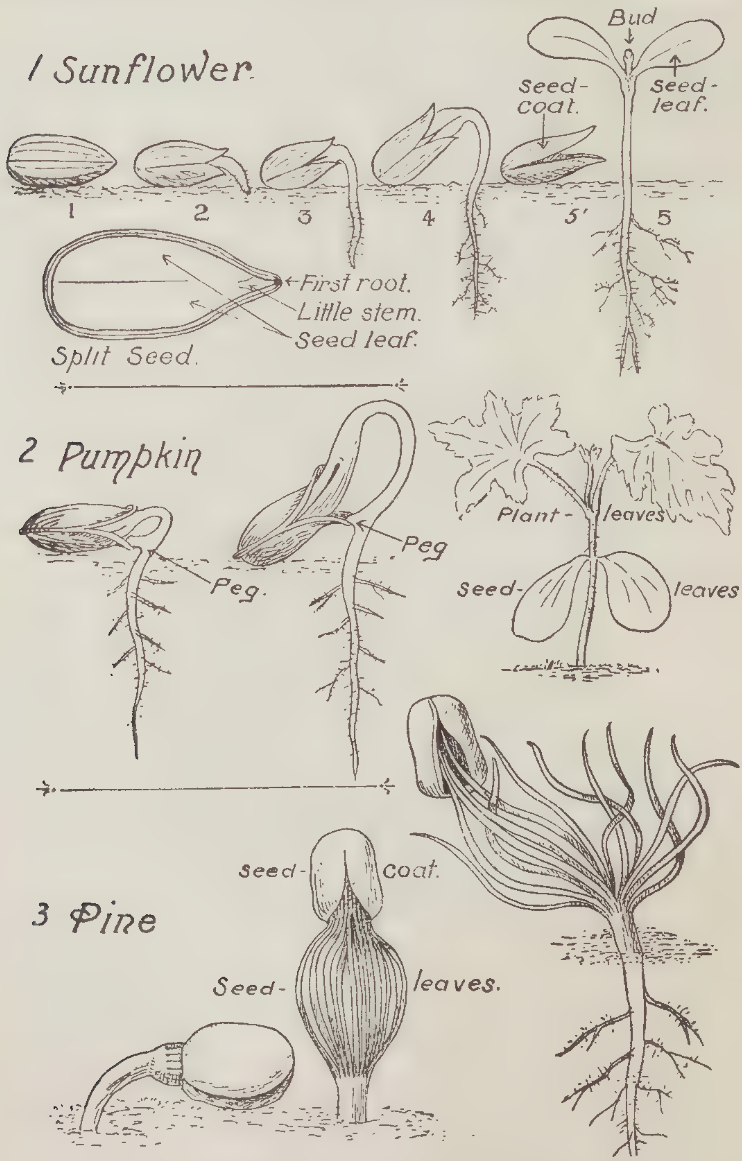

PLATE 2.—GERMINATION STUDIES.

1, Sunflower; 2, Pumpkin; 3, Pine.

Confirm this by examining developing French bean seeds.

"What did the chick do when the food in the egg was used up?" "It came out, and obtained its own food with the mother's help." What will the baby plant do to get its own living when the food the mother provided has gone? Who will grow some peas to find out?" All will.

"How old is the chick when it leaves the egg?" "Three weeks." "To be sure of discovering what the baby plant does, we shall have another lesson on it this day three weeks. There is enough food to last a pea plant for some time.

The life history of the pea should be treated fully, and lessons given when the pea plant reaches the stage treated.

B. Studies in Germination.

A few seeds should be planted first; then, at intervals of three days or so, plant two or three seeds, in order that all stages of development will be represented during the discussion. They provide material for comparison and contrast, and any structure can be traced backwards or forwards. Dated labelled drawings should be made at intervals until the plant has permanent leaves.

It will be noticed that seeds in nature often fall in the best position for germination; that they are sometimes fixed to the soil, so that the root may leave the seed-coat and force itself into the soil; and that the root fixes itself firmly in the soil, and then there is often a struggle to withdraw the seed-leaves and baby stem from the seed-coat.

The first point is illustrated by planting seeds in different positions (4: 5), and noting in which position they germinate best. Is this the position most often taken when they fall?

The second point provides interesting observation work. Many sticky seed-coats (mustard and pumpkin) fix the seed; ridges and spines on seeds help to fix them.

Many plants (pumpkin) illustrate the third point. The root being fixed, the previously curved stem is lengthened (2: 2) and the seed-leaves and stem are withdrawn from the seed-coat, which is held open by a special peg.

A few notes on some common germinations are appended.

The French bean (1: 1) root curves down into the soil, the curved stem straightens, and the seed-leaves are withdrawn from the seed-coat; they are spread out, acting as the first leaves. Soon their shrivelled remains drop off.

The sunflower (2:1) seed lies horizontally. The root grows horizontally, and then curves down into the soil. The seed is raised and the two seed-leaves are steadily with-

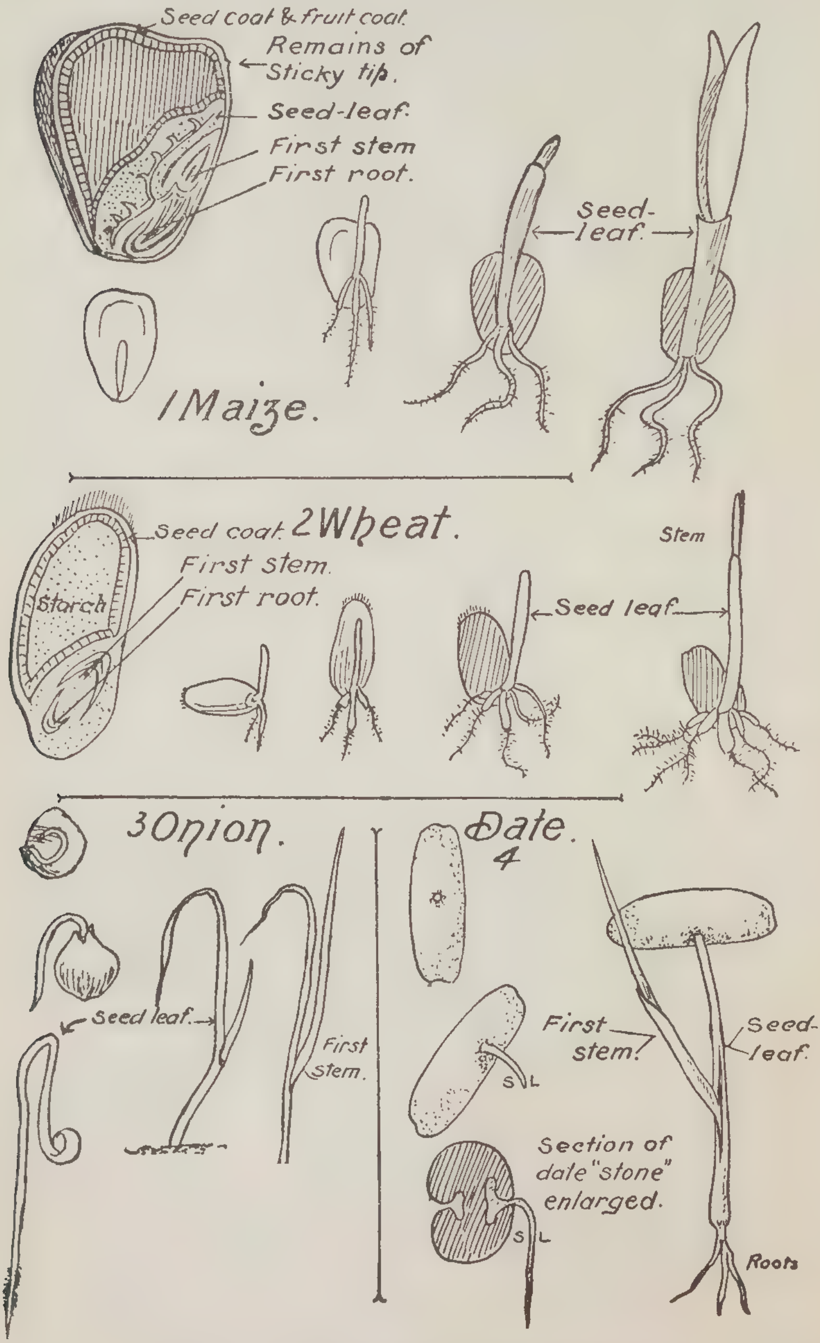

PLATE 3.—STUDIES IN GERMINATION.

drawn from the split seed-coat, which falls. The green seed-leaves function as foliage leaves.

The germinating broad bean (1:3) and acorn resemble the pea (1:2); the seed-leaves are not raised above ground. The seed-coat of radish, cress, and cabbage fasten the seed to the soil, and the little root grows down. The root-hairs fix it to the soil, and the seed is raised. Gradually the seed-coat is worked off, and the two seed-leaves, folded double and occupying practically the whole seed, are seen.

The gourd family, including marrows, pumpkins (2:2), cucumbers, and squashes, provides interesting studies. The seeds lying flat are cemented to the soil by the gummy seed-coat. The root forces its way into the soil, and is fixed by the root-hairs. The seed is raised, and, after a struggle, the fleshy seed-leaves and "little stem" are withdrawn from the flask-shaped seed-coat. The diagram (2:2) shows the ingenious peg which forces the seed-coat open. One of Liberty Bailey's famous nature-studies is entitled, "How the Squash Gets out of the Seed."

The pine (2:3) has many seed-leaves. The diagram shows the main stages until, at last, the seed-coat being worked off, the many seed-leaves serve as foliage leaves. In the seed of the castor-oil plant, violet, and some others, a fleshy mass near the scar assists by absorbing water.

Wheat (3:2; 56:5-6) has one seed-leaf. The numerous roots grow down, and the seed-leaf[1] grows up, forming a hollow sheath, which protects the baby plant; the little stem grows out through the top of this sheath. The seed-leaf acts as a nurse, protecting and feeding the baby plant; it absorbs the food stored in the seed.

Maize (3:1) resembles wheat. The coats of seed and fruit are very close together in maize and wheat, the seed is really a fruit containing one seed. Oat seeds develop similarly, but when the husk is on the seed, the roots appear from one end and the stem from the other, though both the root and stem grow as in wheat.

The seed-leaf of the date (3:4) emerges from the hole on the underside of the stone, and grows some depth into the soil. The "baby plant" at the end of the seed-leaf is thus

[1]Some authorities consider this structure the sheath of the first foliage leaf; others as part of the seed leaf; the latter view is taken here.

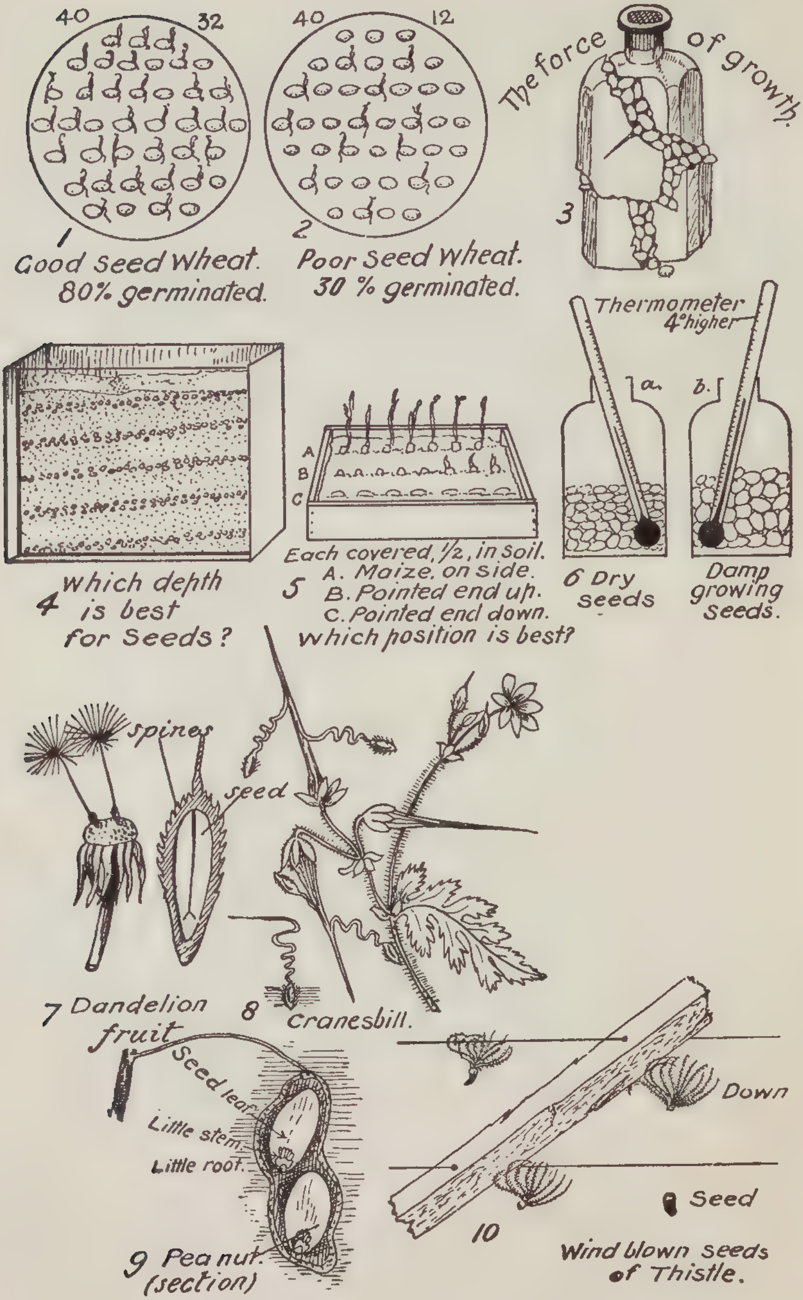

PLATE 4.—SOME GERMINATION AND SEED STUDIES.

1, 2, Seed Testing; 3, The Force of Growth; 4, Depth of Planting; 5, Seed Position; 6, Heat Due to Germination; 7, 8, 9, 10, Seed Planting in Nature.

planted at the proper depth, where it obtains more moisture than in the dry upper soil. Some palms thus place the "baby plant" at a depth of over a foot. The swollen tip of the seed-leaf inside the date-stone absorbs the food (cellulose) stored there. Roots grow down, the stem grows up within the hollow seed-leaf and out through its side.

The germination of the onion (3: 3) resembles, in general, that of the date. The seed-leaf grows out of the hard seed into the ground (3: 3). Then the bent part lengthens upwards, and roots grow out from the "baby plant" at the base of the hollow seed-leaf. The bent seed-leaf sometimes straightens, raising the seed on its tip, which absorbs the food stored in the seed; the empty seed-coat is dropped; the green hollow seed-leaf now functions as a foliage leaf. Soon, however, the "little stem" breaks through its side.

Eucalypts often change the character and arrangement of the leaves, and some acacias (wattles) lose their true leaves and develop flattened leaf-stalks, "phyllodes" (18: 2). In many eucalypts (17: 7) the leaves of the young plant are oval, paired, devoid of a leaf-stalk, and are placed nearly horizontally. On older branches, the sickle-shaped alternate leaves hang vertically. Observe other seedlings also.

C. Some Experiments in Germination.

All seeds are not good—all will not germinate—so that seed testing (4: 1, 2) is important to farmers and other plant growers. Forty seeds are placed on a saucer and supplied with water and warmth. Those sprouting in two days are considered good; a second trial is given the rest.

Seeds swell up when growing, and, as they cannot escape, the bottle is burst (4: 3). Growth is also accompanied by a rise in temperature (4: 6). A thermometer amid developing seeds showed 4deg. F. higher than a similar thermometer in dry seeds alongside.

A good method of setting up germination experiments is to place the seeds in sawdust inside a lamp-glass and keep them damp by standing the glass in a saucer containing water.

Experiments on the proper depth (4: 4) of planting will show the danger of deep planting. In nature, most seeds germinate on the surface. Some, however, such as the

peanut (4:9) are buried; the fruits, often two-seeded, being borne on a long stalk. The proper position (4:5) of the seeds, too, may influence the time and rate of development. The use of the seed-leaf in planting the young date-palm (3:4) and onion (3:3) has been mentioned.

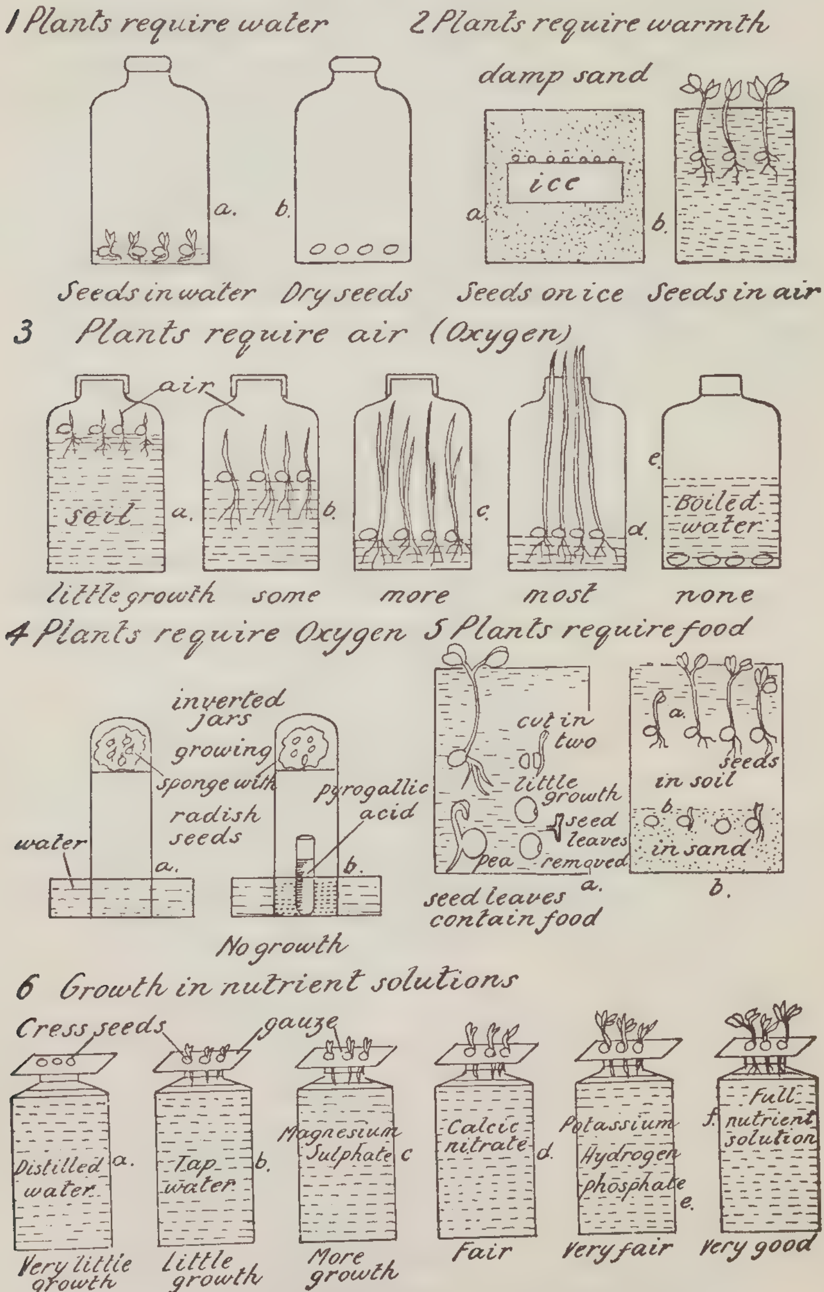

PLATE 5.—REQUIREMENTS FOR GROWTH.
1, Water; 2, Warmth; 3, 4, Air (Oxygen); 5, Food; 6, Nutrient Solution Experiments.

The dandelion seed (4:7; 65:7) with a pappus of hairs, is wind-scattered. It settles vertically amongst grass stems. The top of the seed-box has spines. As the wind catches the pappus, the spines prevent lifting, and the seed settles to the soil. The "clock" (4:8; 66:9), the fruit of the cranesbill (a common plant of the geranium family) has a long tail which twists and untwists according to the amount of moisture in the atmosphere. It is said that these seeds sometimes pierce the body wall of a sheep.

Thistle seeds (4:10) are spread, but not so widely as many think. The seed is soon dropped, and the feathery pappus, often called a "robber," floats on.

D. Requirements for Growth.

There are four prime requirements of the pea plantlet for growth or active life. These are air, water, food, and a certain degree of warmth. That plants require air may be illustrated by a simple experiment (5:3). Three jars, each with four wheat seeds and with varying amounts of soil, are made air-tight with vaseline or plasticine. The seeds germinate and the plants grow for varying lengths of time. In a, three-quarters full of soil, growth soon ceases. In b, half full of soil, growth ceases after a longer time. In c, with little soil, growth continues, for the plants have enough air to develop to the green stage and set free the oxygen again. In d, open fully, growth is most active.

Another experiment (5:3):—Boil some water to drive the air out of it. When it is cold, place in a glass jar and put a few seeds in it. These do not germinate. Why? Others in a similar jar, moistened but not covered with water, germinate. Seeds need air (oxygen)—pyrogallic acid solution absorbs oxygen, there is no growth of seeds when the oxygen is absorbed (5:4b).

It is easy to prove that water is necessary, for dry seeds do not grow (5:1b), and, unless a garden is watered, growth often ceases in dry weather.

Food, of course, is necessary for growth, and the maintenance of life (5:5). Hence there are food-stores in the wheat grain, and other seeds.

Warmth is necessary, as is evidenced by the increasing growth in spring-time, and the "bursting" of buds on plants from other countries. In an ordinary winter in Australia

grasses grow all the winter, though not so rapidly as in warmer weather. To emphasize the point, plant some seeds in soil on a block of ice (5:2), and some in similar soil.

More advanced nature-students could experiment with growth in "nutrient solutions" (5:6). Root food is necessary for the plant. This is largely left as ash when a plant

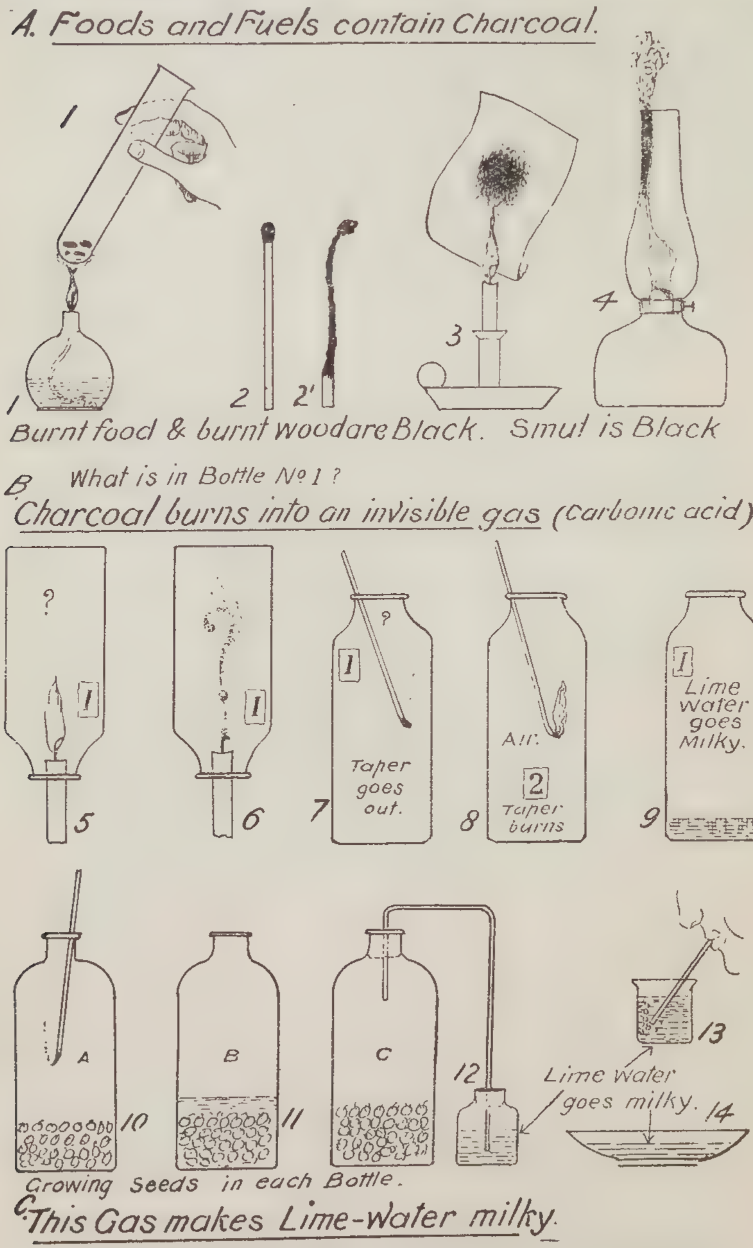

PLATE 6.—EXPERIMENTS WITH FOODS, FUEL AND BREATHING.

is burnt. The root food must contain small quantities of various soil matters; phosphorus and nitrogen are the chief; but potassium, sulphur, iron, calcium, and magnesium are elements also contained in root food.

CHAPTER. II.

A STUDY OF FOOD.

"You are growing peas to discover how the baby plant will live when the food in the seed is exhausted. What is your pea doing?" "It is growing leaves and roots." "Why does it grow leaves? Why does it not get a mouth? Perhaps the leaves and roots will help it to get food. To understand the work of leaf and root, we must find out something about food. We can best do that by thinking of our own food. Name one thing you had for breakfast." "Bread." "What is bread made up of? Do not tell me flour or wheat, or I shall want to know what they are made of. This time, we shall find out in a different way. Suppose you are toasting white bread and forget it, what will happen?" "It will burn." "How will you know when it is burnt?" "It becomes black." "Black!" (incredulously), "What, white bread becomes black?" "Yes." "Who believes that?" Every hand is up. "How do you know?" "I have seen it." "I believe you if you have seen it; white bread becomes black."

"Tell me something else you had for breakfast." "Meat, potatoes, porridge." Elicit that these go black if overcooked. "Is there any food that will not go black?" Perhaps milk is named. Heat some milk or other food over a spirit lamp in a test tube (6: 1), it soon goes black. Establish that food stuffs except salt and water go black.

"What is the black?" No answer. Ask four questions:—(1) "If a piece of bread falls into the fire, what happens?" "It blazes up and goes black." (2) "A piece of paper?" (3) "A piece of white pine" (6: 2)? (4) "A piece of fire-

wood?" Each blazes up and goes black. "What is the black?" City children often say ashes; country children, charcoal. "Think what you have told me. You have said I had charcoal for breakfast. I had porridge, meat, and bread; you said they go black, and the black is charcoal. It is true, I had charcoal for breakfast."

"Suppose mother is cooking with a fire of wood or coals. If the fire is not burning well, what will she do?" "Blow it." "What do you give a fire when you blow it?" "Wind, air." Two things are needed to make a fire burn—fuel (charcoal) and air. Next morning, where is the charcoal which was put on the fire?" "It has burnt to ashes." "From a shovelful of coal would you get a shovelful of ashes?" "No." "Where is the rest?" "Burnt away; gone up the chimney." When a fire burns properly it is all red coals; there is no visible smoke; black smoke is unburned carbon. "We shall light a fire (a candle or a spirit lamp) to discover if anything goes away from it. The candle (6:3) has charcoal in it. You can easily show this, for, when there is a draught, the black smoke dirties white paper (6:3). When the candle burns steadily, there is no black smoke. Perhaps something is going away from it." Hold an inverted pickle-bottle over the candle, with its lip slightly below the lower part of the flame (6:5). Soon the candle goes out (6:6). "What put it out?" No answer. The children are too intent and surprised for words. Light the candle again. Hold the bottle over it as before. The candle goes out again. "What put it out?" "No air could get in." "But the bottle was not closed. Air can get to the lamp at home when the glass is on." Light the candle again. Again it goes out. The pupils cannot suggest any reason. Dip a lighted taper or match into an ordinary pickle bottle (6:8); it burns. Dip it into the first bottle (6:7); it goes out. (Be careful to keep your hand over the bottle, for the gas soon escapes.) The children will perhaps say there is something in the bottle that puts the candle out. "Where did the something come from?" "From the candle." "Yes, the candle burns away, and we have caught some of the burnt-up stuff, 'burnt-up charcoal' (carbon dioxide, or carbonic acid gas). We cannot see, smell, or taste this gas, but it soon shows it is there by putting burning things out."

"You said I had charcoal for breakfast. Have I had any air since?" 'Yes, when you breathe." "Then, perhaps, I give out 'burnt-up charcoal too.' I cannot catch my breath in a bottle and put a candle out; I must show you another way to tell if this gas is present." Hold the pickle-bottle over the candle once more to make sure that the gas is in it. Add about a tablespoonful (6:9) of limewater,[1] remarking how clear it is; shake the bottle well. "Who sees any change?" "The limewater is milky." "We can thus easily discover if this gas is present. Breathe through a straw or tube into limewater (6:13). It goes milky. What does that show you?" "That 'burnt-up charcoal' is in your breath." Let one boy and one girl breathe into lime-water (6:13); it goes milky. " 'Burnt-up charcoal' is in your breath." It also comes away from a fire. The children saw it put a candle and a taper out. It would put a boy out, too. You would drown in water, and you would also drown in this gas. It is difficult to tell if this tasteless, odorless, and colorless gas is present. Relate one of the numerous incidents reported in the papers of miners and "foul air." This gas is a most dangerous thing. "Since we are all breathing it out, why does this room not get full of it?" The pupils look around and see ventilators and open windows; they have had a lesson on ventilation which they will not forget.

"Think of all the wood and coal burnt every week. Think of the thousands of people all breathing out this dangerous gas. Why does not the air get full of it, and drown us all? Later, we can try to answer this question; think about it and try to find out." Since each part of a plant—seed, stem, root, leaf, flower and fruit—contains charcoal, you can endeavor to discover also how the plant gets its charcoal.

Remember the black stuff is carbon (charcoal). The "burnt-up charcoal" is an invisible gas. Try to discover also the use of the leaf to the pea plant.

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[1]Made the day before by adding water to some freshly burnt lime. The bottle should be kept tightly corked and refilled with water each time any is used

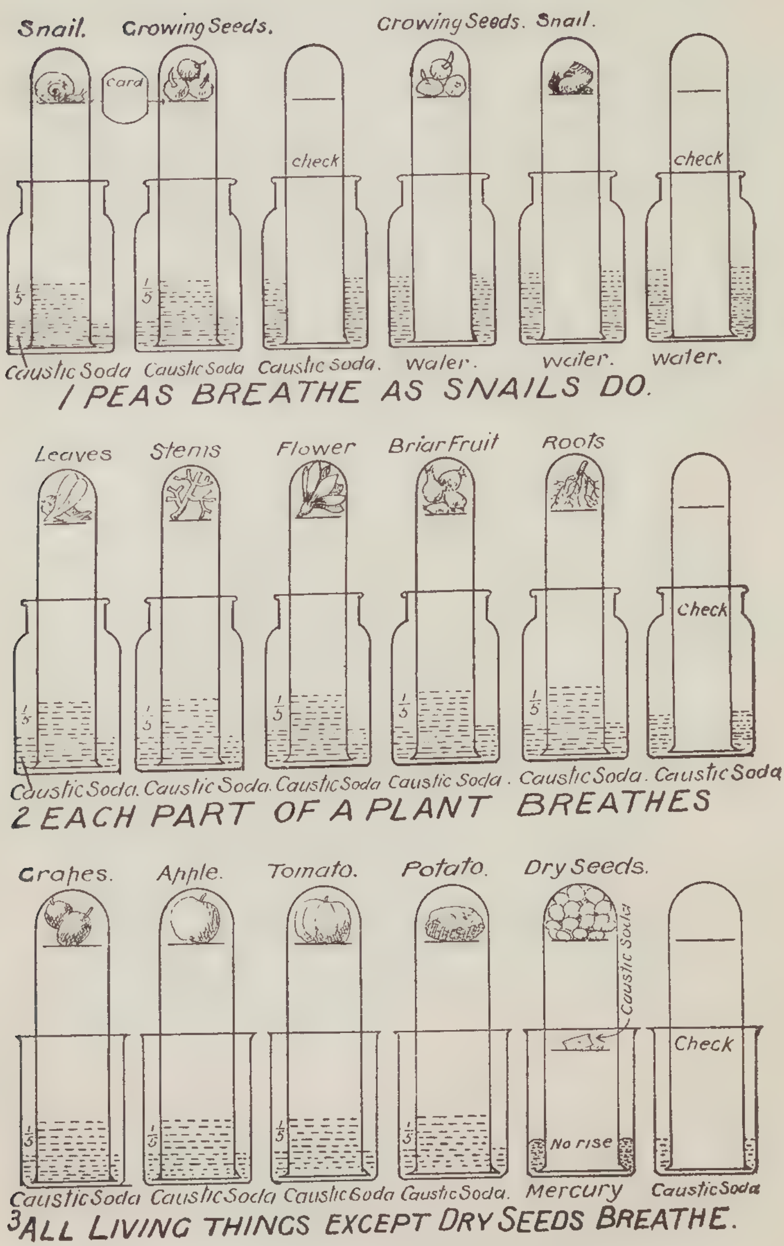

PLATE 7.—THE BREATHING OF PLANTS.

CHAPTER III.

THE BREATHING OF PLANTS.

Animals breathe in oxygen and breathe out carbon dioxide (carbonic acid gas or "burnt-up charcoal"); so do plants. Animals generally have lungs or gills—special breathing organs. Plants have not these specialized organs; each part —seed, root, stem, leaf, flower and fruit—breathes for itself (7:2). Simple experiments will show this, and prove that plants breathe (7:1) as animals do.

Animals and plants breathe in oxygen and breathe out carbon dioxide. To illustrate this, put some peas in one tube and a snail (7:1) in another test tube, place a plug of wadding or a piece of cardboard cut to fit the tube tightly, with a strip off each side to allow the air to pass freely. Invert these in vessels of water containing some caustic soda. They breathe in the oxygen of the contained air and breathe out carbon dioxide ("burnt-up charcoal"), which is absorbed by the caustic soda. The liquid rises one-fifth, proving that some living things breathe in an atmosphere practically devoid of oxygen. When the water has risen one-sixth let the snail go. This experiment is not quite convincing. One of your pupils with the nature-study spirit might object that the water might rise without the caustic soda, or that, when caustic soda is present, the water might rise in an inverted tube without plants or animals. Mount four more tubes—one containing snails and one developing peas—inverted over water without caustic soda, and the other two without living things (7:1) inverted over the caustic soda and water. There is no rise in any of these tubes. Since all the factors are the same in the tubes, except the presence or absence of snails or peas and caustic soda, we have proved that snail and peas made some change in the air in the tube, producing gas which is absorbed by the caustic soda, but affecting only one-fifth of the original volume.

Since we know one-fifth of the air is oxygen, we conclude that the living things breathed in the oxygen present, and breathed out an equal quantity of carbon dioxide ("burnt-up charcoal"), which is absorbed in two tubes, but not in the others. The checks show that the caustic soda alone is not responsible for the rise of the water. In doing any experiment, it is necessary to mount "check" or control experiments, so that only one or two conditions vary, and the student *must* reach the proper conclusion. Experiments without checks are harmful, and develop bad habits of thought. Label the drawing of each experiment clearly as it is set up. Mount in the same way two leaves (7: 2), a piece of stem, two or three fragments of roots, three common flowers, a small potato (7: 3), a small apple, a banana, some grapes or sweetbriar fruits, indeed, any plant parts at all. You will find they all breathe oxygen, and breathe out carbon dioxide, *i.e.*, each part of the plant breathes for itself. The leaf is not the *lung* of the plant. There is no lung in a plant. The mangrove growing in a filthy mud has air-tubes from the roots up to the surface. These are the only specialized breathing structures found in plants. Dry seeds, however, do not breathe (7: 3), they seem to be in a state of "suspended animation."

Place some seeds, leaves, or roots in a damp bottle, cork tightly, and put away for two or three days in the dark. Open the bottle when it is required, pour in a little clear limewater (6: 11), shake vigorously, and pour out into a clean glass vessel. The liquid is milky; therefore carbon dioxide was produced by the enclosed seeds, leaves or roots.

Insert a lighted taper into a jar containing germinating seeds (6: 10). It goes out. Insert it into a jar which contains an apple, a banana, or a potato, and which has stood three days in a dark place; the taper goes out. It is a striking thought that the potato you are peeling is alive and breathing, and the apple you are eating is also breathing.

The two facts for this study are—(1) that plants breathe as animals breathe; (2) that each part of a plant breathes for itself, *i.e.*, the leaf is *not* the lung of the plant.

CHAPTER IV.

LEAF STUDIES.

A. The Leaf as a Feeding Organ.

"Has anyone discovered why the air does not get too much 'burnt-up charcoal' in it?" "The wind blows it away," "Plants take it," are, perhaps, suggested reasons. "Think of an apple; bake it; forget it. It goes black. What is the black?" "Charcoal." A fruit contains charcoal, so does every part of a plant. "Where does the plant get the charcoal?" It gets none from the soil. Even if charcoal is in the soil after a fire, the plant cannot dissolve or use it. The charcoal in plants came from the air. Dwell on this. All the carbon of coal and wood was once floating in the air as an invisible gas, "burnt-up charcoal" (carbon dioxide).

To show that there is some in the air now, examine a saucer of standing limewater (6: 14), or blow air through limewater with a bicycle pump. The limewater in contact with the air becomes milky. Another question suggested for to-day is, "What is the baby plant doing to get its living when the food in the seed has gone?" "It is growing leaves and roots." "To-day we shall think about the leaf. Why does a plant get a leaf rather than a mouth? A mouth would be of little use were there no food to put into it. A mouth like yours would be useless to the plant. The leaf, perhaps, helps it to get food. Hold a fresh leaf to the light. "What do you see?" "Veins" (12: 1; 14: 10). "Who sees veins? Look at your hand. What is in your veins?" "Blood." "How do you know?" "If you cut one blood flows out." "Look at my finger; it needed food and air this morning. The blood taking food and air to it suggests the baker, butcher and grocer bringing supplies. The tiny living cells of my finger took what they required. The burnt-up material and what was not wanted were removed by the blood, thus suggesting to town children the rubbish-man. In the finger are two sets of vessels, one taking blood with air and food material to the finger, and the other taking

blood with waste products away. In the veins of the leaf are two sets of vessels—one taking water and soil materials to the leaf, the other taking food material from the leaf.

"Can you see anything else in the leaf?" "Ribs." "Why has an umbrella ribs?" "Can you see anything else?" Children see hairs, dots, cracks and many unimportant things, but few see the green; most think the green not worth mentioning, but it is the important thing. The veins are white; between the fine veins are patches of green. Speaking generally, plants are food-producers; animals, food-consumers. All our food is prepared by the green. Trace bread to wheat plants; porridge to oat plants; mutton chops to green grass; our clothing to green plants; and common fuels to plants either recent or remote.

We must have a name for the wonderful green. Since it is generally found in leaves, it can be called "leaf-green" (chlorophyll), though it occurs in many stems, *e.g.*, those of the broad bean, and in plants that have no leaves (seaweeds and simple plants). The two important things in the leaf are "leaf-green," the food manufacturer, and the veins conveying raw material to this wonderful cook, and taking manufactured food away.

The leaf, a feeding organ, might be called the "kitchen" of the plant. A kitchen is useless without a cook. "Leaf green" is the cook, and a wonderful cook it is. A cook is helpless without a fire. The sun is the fire supplying the energy for this great work. All our food is prepared by this marvellous cook. Man, with all his laboratories and appliances, cannot produce starch and sugar, simple common substances, and they are produced in the leaf at a low temperature. (Man separates and refines these for his use.) "The leaf is not only a kitchen, it is a chemical laboratory, leaf-green elaborating highly complex proteids and other materials. Leaf-green in sunlight takes the invisible burnt-up charcoal from the air, divides the oxygen from the charcoal, mixes the charcoal with water and dissolved matter from the root, and forms starch and other foods, wood, and other substances. At the same time the good air (oxygen), a by-product here, is given out. Animals take food ready-made, unite it with oxygen to obtain energy for life and work, and give out 'burnt-up charcoal' (carbon

dioxide). All our energy is derived from sun energy through the leaf-green. Leaves imprison sunbeams, and we change some of them into work and heat. The plant in feeding takes the burnt-up charcoal; causes the carbon to unite with water, forming starch and other substances; and gives out the oxygen. The carbon is used over and over again, and the oxygen also is used over and over again. "Over and over again" is the common process of Nature.

In feeding, animals eat complex ready prepared foods; plants take simple substances and manufacture them into complex ones. Excepting a few plants, having a coloring matter allied to leaf-green, only green plants do this. Mushrooms and other fungi live on food already prepared.

You will readily understand now the saying, "To have plants in the room in the daytime is healthy, but to have them there at night is unhealthy. At night plants breathe, using up oxygen. Of course, needing less energy than we, they breathe less vigorously. In the daytime, while feeding and breathing, they use about thirty times more carbon dioxide than they breathe out, and the breathing has no harmful effect.

To show that oxygen is set free, take some watercress or other water plant, put it under a glass funnel in a jar of water (9: 1). Over the funnel invert a test tube of water. Soon minute bubbles of gas rise. This gas is partly oxygen, but usually air is present also. Time is needed to collect a little gas. Place the experiment in sunlight, for the leaf does not work actively in a shaded room. It is also advisable to breathe into the water occasionally to provide more carbon dioxide; the plant requires a volume of carbon dioxide equal to that of the oxygen liberated. A glowing splinter dipped into the gas may burst into flame; oxygen is present.

"Leaf-green" does three things in which we are interested:—1. It takes the "burnt-up charcoal" (which would drown us) from the air; 2, it makes foods, fuels, and materials for clothing; 3, it gives off good air (oxygen).

"Why have we so many green plants about the school and home?" "To use up the bad air; to give us good air; to give shade and shelter." "Who will pluck leaves from a tree?" No one. "Who will protect trees and keep others from injuring them?" All will.

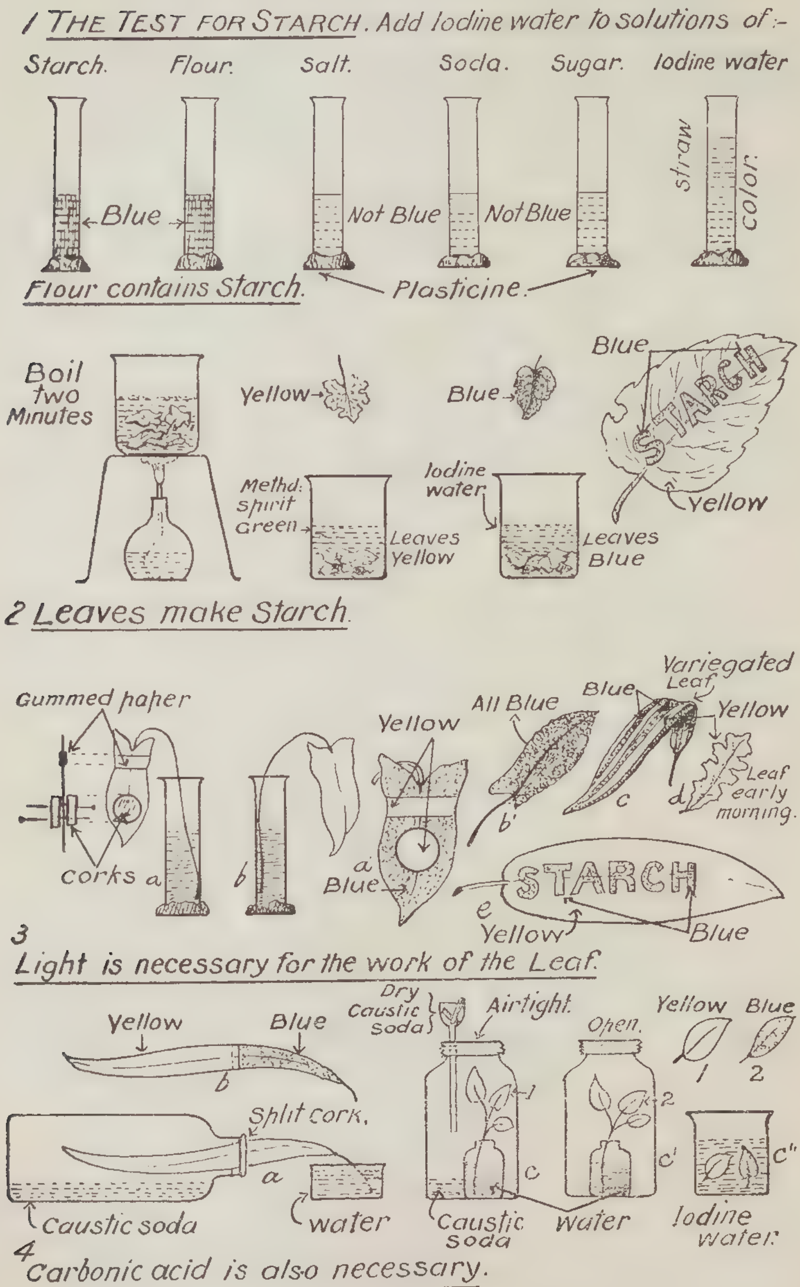

PLATE 8.—STARCH EXPERIMENTS.

1, Test for Starch; 2, Leaves Make Starch; 3, Leaves Need Light; 4, Leaves Need Carbon Dioxide (Carbonic acid gas).

This study generally creates a fine effect, and leads to great care of green plants. When the boy realizes his dependence on plants, he takes a new and personal interest in them, and the common leaf becomes full of meaning and mysterious processes to him.

Simple experiments to illustrate the feeding of plants are easily performed. To show that starch, a simple food, is manufactured by the leaf, take four leaves (8: 2) at three o'clock in the afternoon, and place them in boiling water for two minutes. Leave them in methylated spirit (alcohol) for two days to dissolve out the leaf-green, which is insoluble in water. Wash all alcohol from two leaves and place them in iodine solution, diluted until it is a light straw color. The next day, these leaves will be bluish, while those in alcohol remain light yellow. The blue color denotes that starch is present. To demonstrate this, take some sugar in a test tube (8: 1), add water, shake; add iodine water; no blue; similarly with many other substances. These substances are not the cause of the blue in the leaf. Then try starch. Mother adds hot water when "mixing starch" (which does not dissolve readily in cold water), and we shall warm the starch solution. Allow it to cool and add some iodine water. The solution goes blue. If the solution is warm, it may not go blue; if heated slightly, the blue disappears. Starch gives a beautiful blue solution with iodine water; since the leaf in iodine is blue, it contains starch.

Other experiments (8: 3) prove that "leaf-green" works only in sunlight. Pick two leaves early in the morning and two from the same plant in the afternoon. Test as before. The afternoon leaves go blue; the others do not; therefore sunlight is necessary for starch formation. Put a pot-plant into a dark corner for a day or two. Test two leaves—no blue; therefore, no starch. Cover a living leaf with the word starch cut out of paper (8: 3). Pick at three o'clock; treat with iodine; the word starch appears in blue. Fasten discs of cork (8: 3) or gummed paper tightly on a leaf; pick in the afternoon; test; under the corks the leaf remains whitish; light is necessary for starch formation.

The dense coloring in the skin of a variegated leaf acts as the corks did. Test for starch. The leaf (8: 3c) goes blue only where it showed green. Other experiments (8:4)

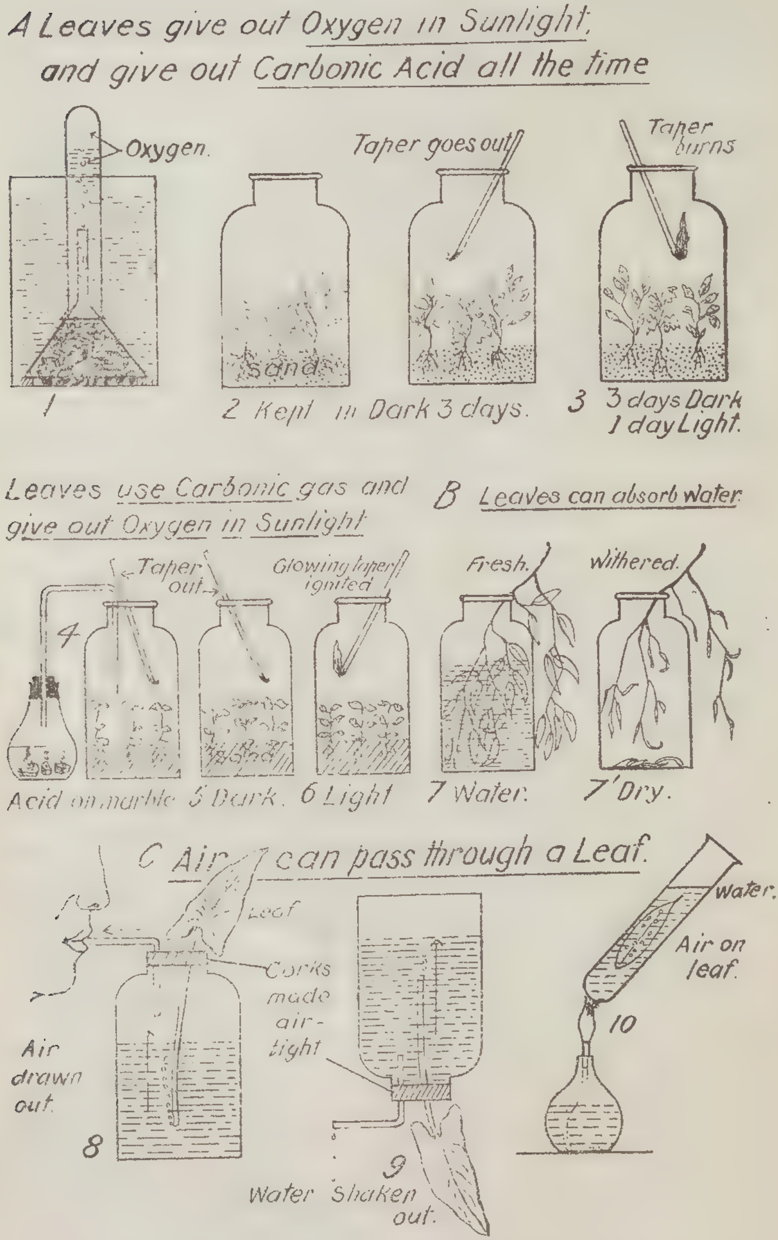

PLATE 9.—EXPERIMENTS WITH LEAVES.
A. Leaves give out oxygen; B, Leaves can absorb Water; C, air can pass through a leaf.

demonstrate that, to make starch, carbon dioxide ("burnt-up charcoal") is necessary; when a leaf cannot get carbon dioxide, it cannot make starch; it cannot make something out of nothing. Choose a growing twig with two large leaves, place one in a jar containing caustic soda (8: 4c), and the other in a jar of air (8:4c¹). Plug the jars round the leaf-stalks with wadding (10: 5) to keep them steady; leave them on the tree for some days; in the afternoon, pick these leaves and the leaf alongside, test for starch. The leaf from the jar with caustic soda does not go blue, the others do. Since the difference between the jars was the presence of caustic soda, which dissolves carbon dioxide, it is inferred that carbon dioxide is needed for starch manufacture.

A variation of this experiment is to take, early in the morning, a long narrow leaf. Insert the leaf in a split cork so that it is half outside and half inside a pickle bottle (8: 4a). Seal the bottle which contains caustic soda (preferably solid) to absorb any carbon dioxide. Test in the afternoon. Half the leaf should be blue, and half not blue.

To illustrate that plants using carbon dioxide give out oxygen, grow some plants (9: 2) in air-tight jars in the dark for three days. The jars become filled with carbon dioxide breathed out by the plants. Insert a lighted taper; it goes out (9: 2). Place in the sun in the morning; test with a lighted taper in the afternoon (9: 3): it burns. Some carbon dioxide has been used and oxygen liberated.

A variation is to fill the jar containing growing seedlings with carbon dioxide (9:4) formed by pouring dilute acid on marble; this gas extinguishes a lighted taper (9: 5). Place the jar in sunlight for some time. Test with a lighted taper; it burns freely (9: 6). A glowing splinter bursts into flame, proving that oxygen is present. Carbon dioxide has been used by the leaf, and oxygen is in its place.

The next point to illustrate is that the leaves give off much water. To demonstrate this:—1. Take five similar test tubes (10: 2). In *a* put a leafy twig; in *b* a twig with two or three leaves; in *c*, a bare, living twig; in *d* a dead twig; *e* is a "check" or "control." Fill all with water to the same level. The evaporation from the surface of the water is about the same from each. In two or three days, the tube with the dead twig has lost little water; the bare living

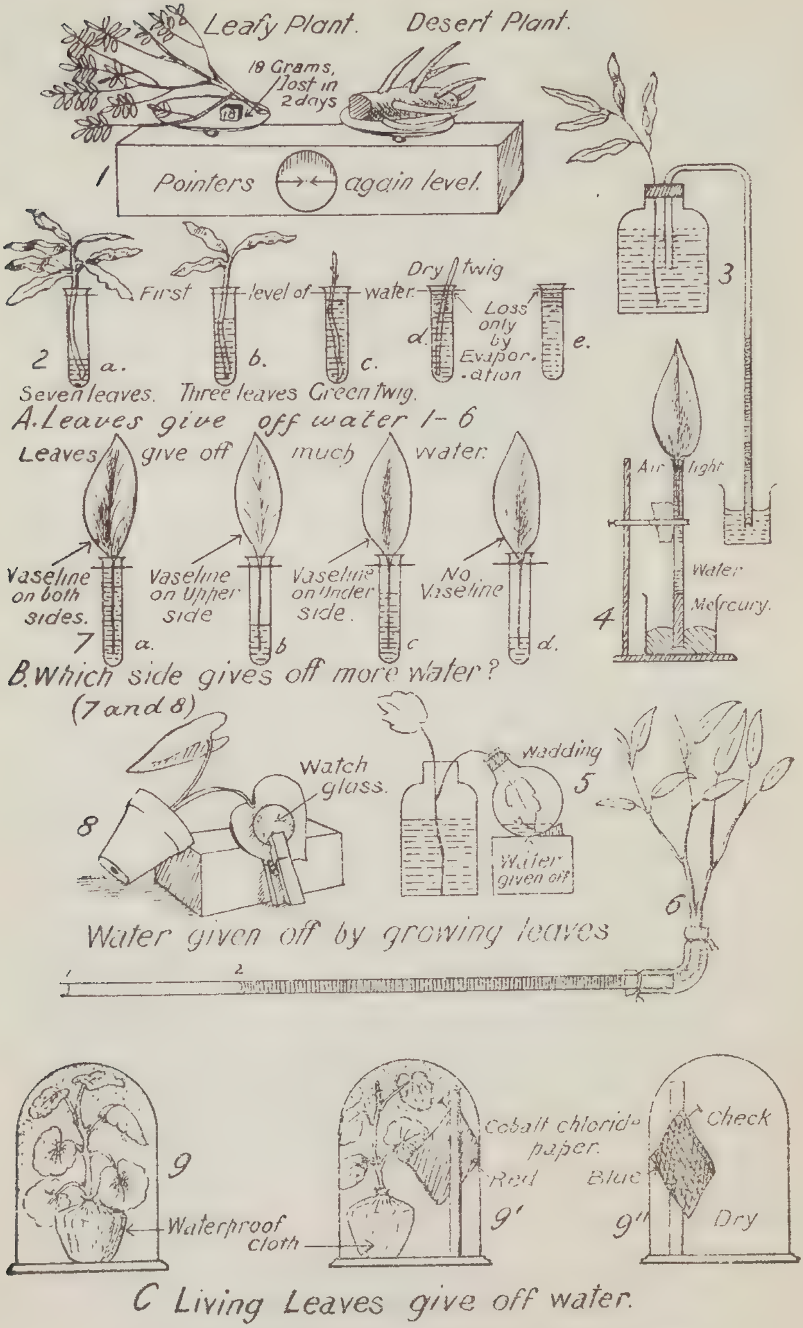

Plate 10.—LEAVES GIVE OFF MUCH WATER.
Transpiration Experiments.

twig more; the twig with few leaves much more; while the leafy twig has almost emptied the test tube.

This is so important that many experiments should be performed to establish clearly that leaves give off water.

One variation is a leafy twig inserted in a long, narrow glass tube filled with water (10: 6); note the water surface as it retreats in the tube. Two further variations are figured (10: 3, 4). The following experiment emphasizes the fact. Place a flask on a large fresh leaf (10: 5); plug the neck with wadding; let it remain on the tree for two or three weeks. When the large quantity of water given off by one active working leaf is seen, all realize the importance of "transpiration." Another experiment is shown where a living pot plant (10: 9) with waterproof material tied securely round the pot is covered by a bell jar. This experiment can be varied by enclosing a piece of paper ($10: 9^1, 9^2$) made blue with cobalt chloride; as water appears the paper becomes pink.

The leaf has an impervious covering; but many minute pores in it allow gas to enter and escape. These minute pores are provided with guard cells, which, when water is being lost too freely, collapse and lie side by side, thus closing the pores. When water is abundant, the guard cells swell and curve apart, allowing gases to pass in and out. The formation in the wet season of a film of water over the leaf must be prevented, for it closes the pores. Many leaves prevent the pores from being closed by a water film.

Some leaves, *e.g.*, cabbage (187: 20), are not wetted; the water gathers into drops and the leaf surface is dry. Dip a leaf of garden nasturtium (187: 22) or cabbage into water; draw it out, it is dry. An apple leaf (187: 21) so treated is wet above and dry below. The side on which the pores are situated is dry. The other side has an impervious skin, and may be wetted without disadvantage to the plant. The leaf of some plants may be dry on both sides, therefore it can be inferred that the pores are on both surfaces. Kerner stated that 80 per cent. of leaves have the upper side wetted and the lower side dry; and 10 per cent. the upper side dry, and the lower wet; and the balance, both sides dry. In floating plants, the pores are on the upper side.

Stand in water or place on a bench four leaves with long stalks (10: 7). On a, cover both surfaces with vaseline to

block up the pores; on b, smear the upper surface; on c, smear the under surface; leave d untouched as a check or control. Which loses its water first, *i.e.*, which withers first? On which side of the leaves are the pores situated? If the vaseline on the under surface kept it fresh longer, then we could infer that the pores were on the under surface, and so on. A variation is to fasten a watch-glass on each side of a leaf (10:8). Which side gives off more water? The pores, invisible to the naked eye, are so minute that there may be millions of them on one leaf such as that of a sunflower or cabbage.

Some plants have a hairy surface. The water film forms across from hair to hair; the pores being open below, work is carried on. Some leaves, *e.g.*, bamboo and grass, have small pegs on them. In wet weather, a film forms from peg to peg, and the surface of the leaf is dry. Note the

PLATE II.—LEAF MOSAICS AND ARRANGEMENTS.

drops on the leaf, instead of a uniform film, spread over it. Other leaves, *e.g.*, eucalypts, are elongated, and have a long point (187: 19) probably enabling the water to drain to the end and drop off. The rest of the leaf can then work.

To show that leaves can absorb water (9: 7, 7^1), take two double twigs and place each with one part in a glass vessel and the other outside of it. Partly fill one vessel with water, and leave the other without water. The leaves on one twig continue fresh; they are supplied with water absorbed by leaves which are in the water. The leaves in the check experiment die. Leaves, however, do not usually function as water-absorbers.

Experiments figured as (9: 8, 9) also show that leaves are porous, for air passes into or through them. Experiment 9: 10 shows that warming a leaf in water expands the air contained in it, and bubbles appear on the surface.

One great need of a plant is *light*. Leaf-green, the cook, cannot work without power or energy—light. Should plenty of food be present, as in seeds, plant growth is more rapid in the dark than in sunshine, and more rapid in diffuse than in bright sunlight. But growth in the dark is an unhealthy growth; it adds nothing to the total dry weight, for no additional food is manufactured. In a cloudy, gloomy season or country, plants take advantage of all available light. The leaves of the "scarlet geranium" plant fit together like so many tiles forming a mosaic. The leaves of ivy (11: 3) marsh-mallow, and garden nasturtium fit well, small leaves fitting between the larger ones; no light is wasted. The lower leaves, having a longer stalk, place their blades beside those of the upper short-stalked leaves. Look down on the top of an erect plant shoot; the leaves are arranged all around it (61: 1^{11}). Count how many leaves are in the circle. If there are three or four, the leaves are probably nearly circular; if five, they are oval, *e.g.*, elm and oak (11: 1a, b); as the number increases, they are narrower. Eight leaves are common in the Pittosporum (61: 1); they are lengthened ovals.

The daisy (11: 5), dandelion (65: 2), flatweed, ribwort (11: 4, 66: 6) and many other plants form "rosettes." The leaves narrow at the inner end, are rounded and wider at the outer; more fit in a circle, and there is little overlapping.

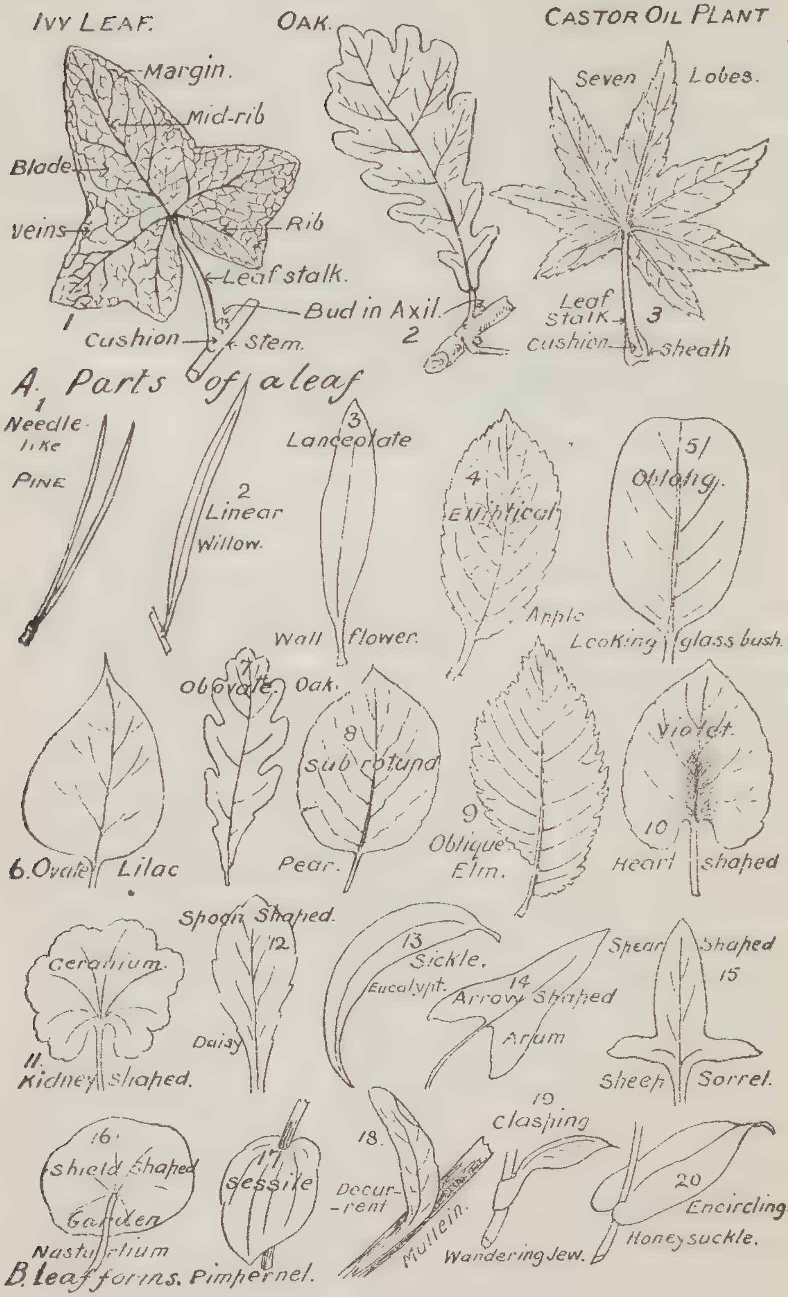

PLATE 12.—LEAF STRUCTURES.
A, Parts of a Leaf; B, Leaf Forms.

There are usually two circles of leaves (66: 6). The inner has the leaves more erect and shorter, the outer spoon-shaped leaves are horizontal and white where shaded.

The leaves of lateral shoots (11: 1a) face the light. Infer from their position the side from which the light came. Fasten an erect shoot horizontally and a horizontal shoot vertically. The leaves will tend to assume the best position as regards light. Stand a horizontal shoot in water with the back of the leaves to the window. The leaves will, if possible, turn over to face the light. Long-stalked garden nasturtium leaves (25: 1) are suitable for this experiment. Town dwellers are often fortunate for nature-study, because so many foreign plants that habitually use all available light can be studied, as well as Australian plants that avoid light.

The arrangement of leaves (11: 6-9) on the twig is regular and interesting, though in the living leafy twig, obscured by the light position taken up by the leaves. The ivy (11: 3) has all the leaves facing the one side, though the leaves originate regularly round the stem. Lilac (11: 6) has opposite leaves, while many plants have alternate leaves (11: 7). Some have whorls (11: 8) of leaves, three, four or more arising at the one level. The larch has small tufts (11: 9) of leaves arranged on the stem. Rosette plants usually have a very short stem, so that the leaves seem to originate from the root, and are called radical leaves (11: 10), though they really originate from the short stem.

B. Parts, Structures and Forms of Leaves.

The flat part of the leaf (12: 1) is usually called the blade. This is supported by a leaf-stalk, whose base is often swollen into a cushion; and there may be in addition a sheath (12: 3) or two side pieces called stipules (15: 1-8).

The shapes (12: 1-20) and margins (14: 1-8) of the leaf-blades are various. Good observation work can be obtained by studying shapes of leaves, kinds and uses of leaves (13: 1-21), edges of leaves (14: 1-8), veins (14: 9-12) and leaf-stalks (14: 13-24), stipules (15: 1-8), and compound leaves (15: 9-20; 16: 1-8). The forms and functions are various, and adaptations and modifications are endless.

Many leaf shapes are shown on plate 12, while many kinds and forms of leaves are shown on plate 13. As each is illustrated by a drawing, verbal description is unnecessary.

PLATE 13.—KINDS OF LEAVES.

9, Blackberry; 13, Prickly Pear; some authorities regard the spines as reduced leaf structures; 18, Dandelion.

Leaf edges (14: 1-8) vary from entire in lilac, to serrate in apple, biserrate in the rose, dentate in the barberry, crenate in the scarlet geranium, sinuate in oak leaves, lobate or lobed in ivy, and dissected, or cut, in the Marguerite.

Veins (14: 9-12) are parallel in grasses and lilies and generally in the plants with one seed-leaf. They are usually net veined in some form in the plants with two seed-leaves. The main veins are arranged as in a feather (pinnate) (12: 9), or resembling the fingers and palm of the hand palmate (12: 3 and 16: 8). The eucalypt (14: 12) has a marginal vein; walnut leaves have looped veins (14: 11).

Leaf stalks (14: 13-24) of many forms and many functions are illustrated. The long, flexible leaf-stalks of poplars (14: 18), including the aspen, enable the leaf to adjust itself rapidly to wind and storm, and save the leaves from damage. The hollow leaf-stalk (14: 19; 58: 3) of the plane protects the developing bud effectively.

Stipules (15 · 1-8), too, present variety of form and function. They fall from many old leaves, *e.g.*, apple (62: 5, 4).

Our remarks, so far, apply rather to leaves of fairly regular outline.

Examine dahlia (15: 10), rose (15: 9), blackberry (16: 1-5), pepper tree (59: 3), and chrysanthemum plants; the leaves do not grow on the outer side, making one mosaic. Leaves, if entirely regular on the edge, might partly cover or shade others. Shaded parts, as have been shown, are useless for food manufacture, and may as well be cut out. Outer dissected leaves let light pass to those below. Even if some leaves are shaded at one period, the changing position of the sun gives them a chance to get light. A remarkable plant, one of the Arum family, has holes in the upper leaves allowing light to pass to those below. Some leaves are cut almost to the midrib. Sometimes, as in the broad bean and rose (15: 9), the leaves are completely divided to the midrib, and a compound leaf, with several "leaflets," is formed, each seemingly a perfect little leaf; the whole structure, though it apparently bears usually five "leaves," is one compound leaf, and the apparent "leaves" are "leaflets." Examine the leaves of many plants. Are they simple or compound? Between leaf and stem is a bud—one bud, one leaf. Compound leaves have only one bud. Inspect the

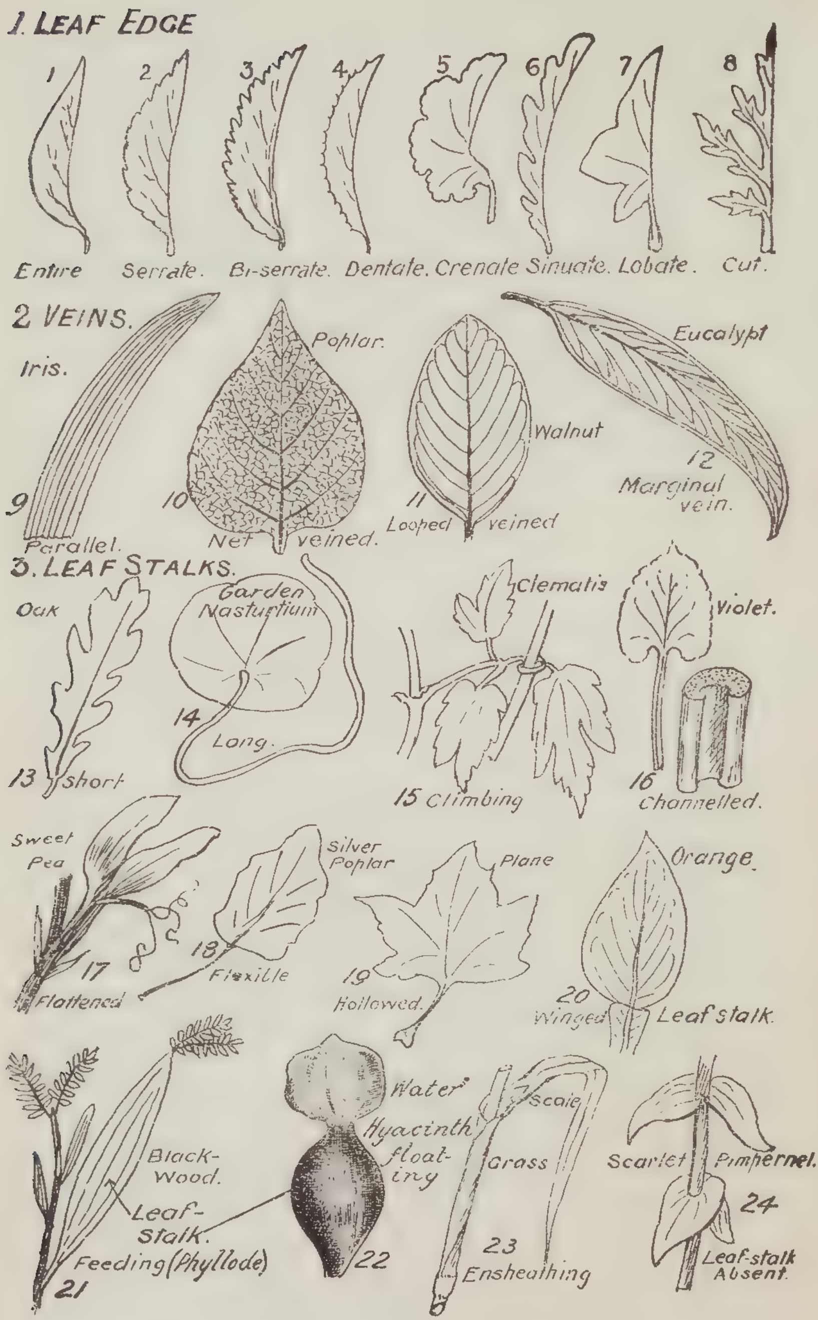

PLATE 14.—LEAF STUDIES—Edges, Veins and Leaf-Stalks.

leaves of the blackberry (16: 1-5); a few are simple, but most are compound; some have well-marked lobes on the leaflets, others are of a regular form.

With much-dissected leaves and compound leaves, the upper leaves are, as a rule, not smaller than the lower leaves, and the leaf-stalks are not longer, nor are the lower leaves more horizontal. Light for them comes through the gaps in the leaves above, and they do not need to place themselves as entire, or nearly entire, leaves do.

Leaves are usually unsymmetrical in shape, and no two are alike. They are living things, and are remarkably modified and altered to meet their environment.

Compound leaves vary in the number and arrangement of the leaflets. In the dahlia (15: 10) the leaflets are sometimes incompletely divided. The rose has a pinnate compound leaf (15:9), while the Virginia creeper (15: 12) and the horse chestnut (16: 8) have palmate compound leaves. The number of leaflets varies from one in the orange (15: 16) to many in the Robinia (15: 17). In the scarlet runner (15: 18) each leaflet has the equivalent of a stipule, here called a stipel. Some leaflets, as in the sweet pea (15: 19), are modified into tendrils (climbing organs); while in the vetchling (15: 20), all leaflets are tendrils and the stipules function as leaves.

The bi-pinnate (leaflets pinnate as well as the whole leaf) acacias, called wattles here, have glands (16:7) at the junction of the main side ribs with the midrib. Possibly, these secrete honey to attract ants that would protect the plant by keeping harmful animals away. These acacias were called wattles because the early settlers found them easily worked in the wattled sides of their "wattle and daub" huts. Many species of plants, but especially acacias, provided suitable long, flexible poles for this work.

Now, the question arises: do leaves take any part in directing water falling as rain to the parts using it?

Plants may be roughly divided into two groups. Those with leaves directing water outwards (16: 13). The water is dropped from leaf to leaf, and reaches the ground under the outer circle of leaves. Such plants probably have shallow, wide-spreading roots. The rain-water is dropped where it is most required.

PLATE 15.—STIPULES AND COMPOUND LEAVES.

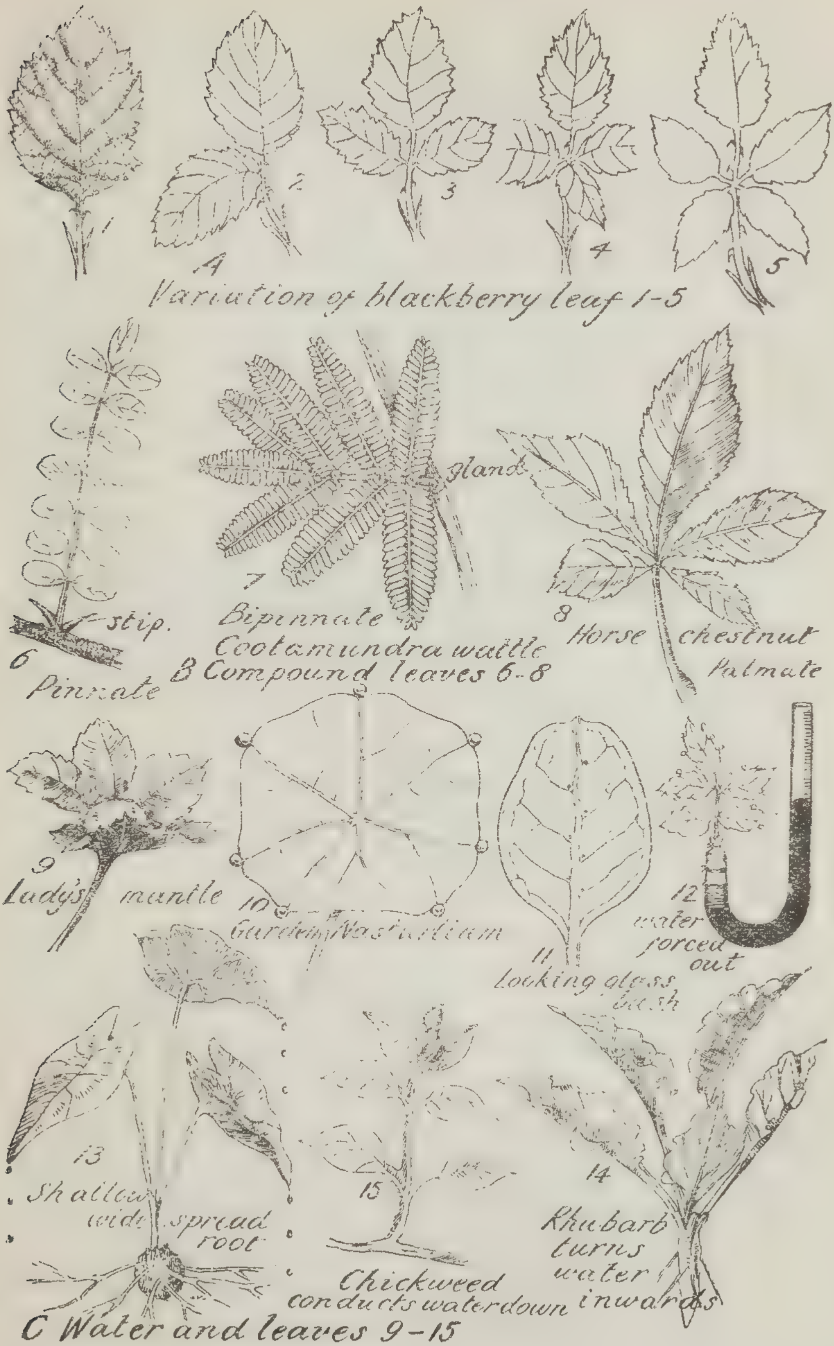

PLATE 16.—LEAF STUDIES.

A, Variation. B, Compound Leaves. C, Leaves and Water.
6, Robinia: 12, Mercury Forces Water Through Leaf.

Secondly, other plants, such as rhubarb (16: 14) and the cannas, turn water inwards. These have long tap roots, and the water is required at the center.

Leaves carrying water inwards have often a channelled leaf-stalk, *e.g.*, violet and rhubarb. Further, this stalk can be wetted, that is, the water wets it, runs down and, at last, reaches the root.

When we look at a fairly regular leaf, the shape often indicates approximately how many leaves grow in the circle. The channelled stalk shows it conducts water inwards, or the round stalk shows it probably turns the water outwards. The dry upper or under side, or both, often show where the pores are. The long stalk will show that the leaf probably grew lower on the erect shoot, while a short stalk will show that it probably grew near the top of the shoot.

Chickweed, with hairs on alternate sides of the stems, conducts water down to the root though possibly some of these hairs absorb water. The leaf of the "lady's mantle" (16: 9) holds a large drop of water. This probably protects the plant from grazing animals which hesitate in cold weather to take in too much cold water with the plants eaten. The drop does not wet the leaf, which continues its work. Tall clumps of capeweed (67:7) possibly also have such a protection in winter; they are avoided by animals.

The garden nasturtium (16: 10) has special water pores as many other plants have. On cold nights, water is squeezed out of many leaves. Water turning into ice expands one-tenth of its volume. This expansion would rupture the plant tissue; many plants give off water from special pores on frosty nights and escape destruction. Much of the so-called dew on the grass is water given out by plants. By means of an experiment (16: 12), water may be forced from these special water-pores by the pressure of mercury.

On the back of the varnished leaf (16: 11) of the looking-glass bush (*Coprosma*) are holes at the junction of the midrib and main side ribs. Two explanations of these have been given. First, that they are dwelling places provided for certain ticks—"police" that eat plant pests. This would be an interesting partnership—plants providing shelter, and animals (police-animals) keeping the plants free from pests. The matter is not yet settled. Observation would be valuable. The second explanation is that they are water-pores.

c. Plants and Dry Weather.

Water is necessary for life; it is present even in the hard parts of plants and animals. The seed-coats of stone fruits and wood contain at least 10 per cent. of water. Water is combined chemically with other substances, forming starch, sugar, proteids, and other compounds. About 66 per cent. of the animal and plant body is water.

Again, water is necessary to convey other substances to the parts of the body needing them; the blood is largely water (75 to 80 per cent.); plant sap contains much water. The demand for water in animals and plants is great; water is usually streaming into and out of plants. Water must not stream out of plants when it cannot be replaced; loss of water is regulated. Without water, life cannot exist except in a state of suspension, as in dry seeds, the eggs of many animals, and plants and animals in a resting state. With increase of water, active life is resumed. Plants living under conditions where a period unfavorable for growth sets in reduce loss of water, or things will go badly with them.

Desert plants must live long periods without water. They must grow quickly, *i.e.*, use much water when conditions are favorable, and reduce the loss of water in unfavorable conditions. Grasses may be considered plants adapted to dry conditions. In Australia they grow quickly, soon flower, seed, and die off; but the future has been provided for; the seeds are there, and drought cannot hurt them. With the next rain, the plants grow quickly. Similarly, bulbs, corms, tubers, underground stems are an advantage, for all is ready, and as soon as conditions as regards warmth and water are favorable, rapid growth is made.

Permanent (perennial) plants show other means of meeting dry conditions. They lessen the surface that gives off water. Think of it in another way, since a plant, of course, does not deliberately reduce its surface. Of ten plants, no two are alike: one may have a reduced leaf surface, and one a greater evaporating surface.

If the drought is prolonged, all might die except the one small plant with the reduced surface; nature favors the stunted, hard plant for desert conditions. Many plants, *e.g*, eucalypts, place the leaves vertically, edgeways to the sun.

In young "blue gums," the stalkless leaves (17:7) placed horizontally and in pairs, may be oval or sometimes nearly circular. Older trees bear different leaves. These are elongate and sickle-shaped (17:7); grow singly, with long leaf-stalks; and hang vertically. Young shoots on an old tree sometimes bear the stalkless leaves. The leaves figured

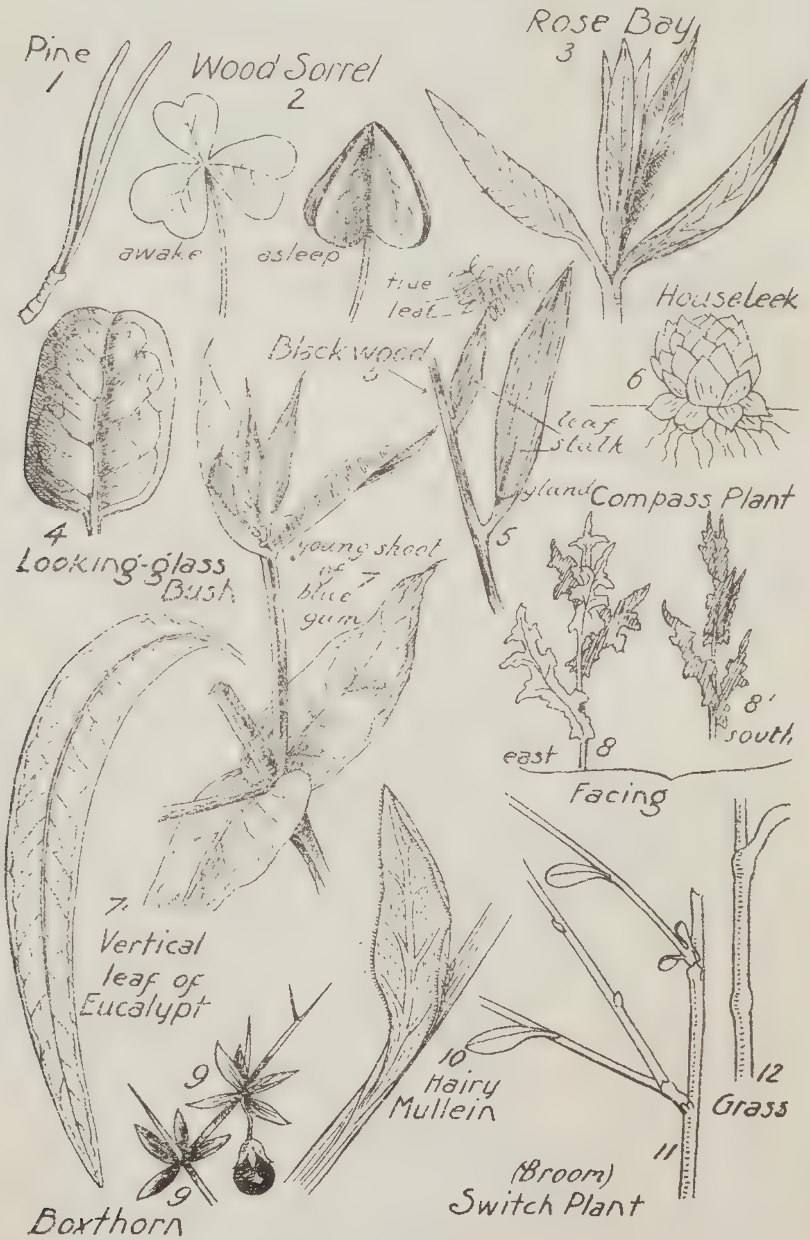

PLATE 17.—PLANTS AND DRY WEATHER.

(17:7, 7[1]) were from the same tree at the same time. Since in the life-history of the individual the life-history of the race is often repeated, it is inferred that eucalypts have probably descended from ancestors that had broad, rounded, stalkless leaves arising in pairs, and placed horizontally, and that they gradually changed to meet the conditions of this sunny land. Some would argue that this indicates a change in the climate of Australia.

Many Acacias, notably the lightwood (17:5; 18:2), the blackwood, and the golden wattle, living under similar circumstances to the eucalypts, have acquired similar leaf habits—an example of "convergence." To reduce the large surface of the feathery leaves and acquire a flat, vertically-hanging "leaf" like the eucalypts, the leaf-stalk has been flattened into a "phyllode," and the true leaf has been reduced, and, in some adult plants, is seldom seen. Young lightwoods and blackwoods, or new shoots on old trees, often bear the true feathery (bipinnate) leaves. It is easy to select a series where the feathery leaves are getting smaller, and the leaf-stalks flatter, until the "phyllode" resembling in form, but not in origin, a eucalypt leaf, is obtained.

With a return to normal or wet conditions, the plant did not return to the feathery leaf, but developed the phyllodes until they were as large as, and doubtless as efficient, food-producers as true leaves.

A study of seedlings and the leaf changes until permanent form is assumed will interest all and provide good study.

Some plants have a covering of hairs (17:10); others are coated with wax; others, like the looking-glass bush (*Coprosma*) have varnished leaves (17:4), which reflect much light and heat; others have a thick skin or cuticle; other leaves become leathery and tough, as in evergreens.

Again, some leaves roll up; the edges turn under and imprison air over the minute pores. The native heath (*Epacris*) and many other water-saving plants have "rolled edges." Many leaves have the edges rolled downwards; a few roll the edges upwards, for the pores are usually on the lower side. Some plants, *e.g.*, eucalypts, have an oil; this is given off, and, as light and heat do not pass through the vapor as easily as through pure air, the oil probably serves as a protection in hot weather.

Some leaves, *e.g.*, marshmallow, follow the sun to get more light. These are usually plants from countries where there is a deficiency of sunlight. Deciduous trees usually have the leaves placed horizontally. Australia has excess of sun. Some Australian plants (eucalypts) protect themselves by allowing the leaves to hang vertically (17: 7, 7^1). Others take a permanent position in which the leaves receive least sun on the average for the day. The American "compass plants" (17: 8) have the long axis north and south.

Again, some plants of rocky places and artificial rockeries, *e.g.*, pigface (13: 11) get little water in nature. They have reduced leaf surface in proportion to their bulk, and often have water-holding substances in the sap, *e.g.*, gums and mucilage; they lose little water. The pig-face and allied plants turn blue litmus red in the morning; it is stated that they store their own carbonic acid gas (carbon dioxide) instead of letting it escape. In the sunlight, this is manufactured into starch. Later in the day, the plant is less acid. Many plants, *e.g.*, house leek (17: 6), have thickened leaves with reduced surface in proportion to their bulk.

Take different twigs of equal weights (10: 1) and place them side by side on a table; weigh each daily and record the weights. Some, *e.g.*, cactus plants, pig-face (*Mesembryanthemum*), bladder plants, sheoak, and boxthorn, lose little weight and show little sign of suffering in hot weather; others lose much weight and wither. One (10: 1) lost in two days 18 grams less than a leafy plant. List such.

Others store water when times are favorable; they have been compared to the camel, "the ship of the desert." The water-cells often look like clear bladders, hence the names ice-plant, crystal plant. These cells open inwards, supplying water as required. Bottle-trees and currajongs also store water.

Some desert plants are deep rooted; though the surface soil is dry, they get water from greater depths. The common wood sorrel (17: 2) has its leaves folded on hot days as well as on frosty mornings. The leaves take the "sleeping position." Plants that live about mineral waters or salt water often have some means of overcoming any harmful effect. They live in a state of drought (physiological drought) so far as fresh water is concerned. Hence, salt-

bush and similar plants flourish in the interior of Australia and along the seashore, where fresh water is scarce. The presence of salt-bushes in Central Australia is not necessarily an indication that the sea once covered that part.

Winter cold in Europe is comparable in this matter with summer drought in Australia, for plants cannot get water from the frozen ground, and leaves might lose water which cannot be replaced. Hence, many plants growing there shed their leaves. The evergreens have thickened cuticle, leathery leaves, or other modifications as in desert plants.

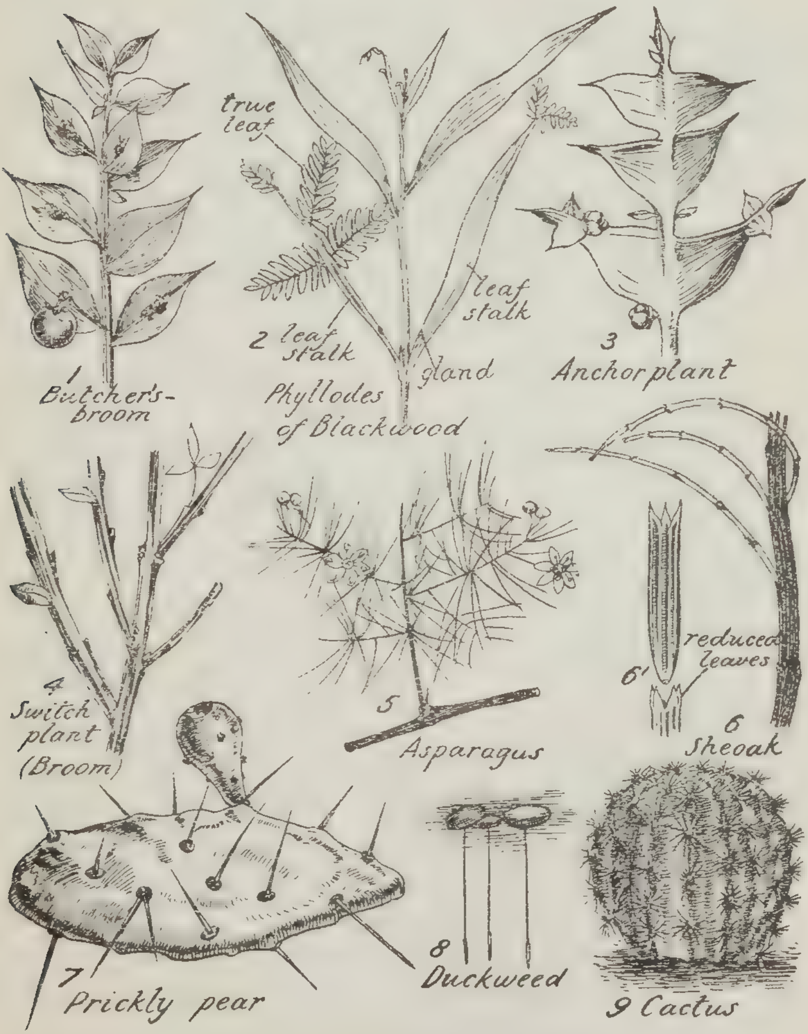

PLATE 18.—LEAFLESS PLANTS.
9. The Vegetable Hedgehog.

D.—Leafless Plants.

Several plants are grouped as "leafless plants." They include many "desert plants." The leaves of some brooms (17: 11; 18: 4) are much reduced, though there are usually some present; the plant depends chiefly on the stems for feeding. In a wet season, many fairly large leaves are present. The garden anchor plant, *Colletia* (18: 3), with flattened stem structures, also bears an occasional small leaf in a good season. In the needle-bush (*Hakea*) the leaf is reduced to a round pointed structure. Sometimes the leaf is reduced to a spine, as in the prickly pear (18: 7), where the fleshy, much-flattened stem functions as a leaf, and the plant loses little water. It is said that a cactus (18: 9) gave off the 6000th part of the water given off by an equal weight of a leafy climbing plant. Some of these plants when left out of the ground for weeks still retain their vitality.

The Asparagus (18: 5; 33: 4) has green stem structures (cladodes) that function as leaves. The true leaves are brown scales (30: 9, 9^1) at the junction of branch and stem. Butchers' broom (18: 1), a plant belonging to the lily family, has leaf-like "cladodes," which bear flowers and fruit. The small scale at the junction of flower-stalk and cladode is the true leaf.

The floating flattened stems of duckweed (18: 8; 187: 24) allow of its being grouped here with "leafless plants" (18: 1-9). One of the most interesting of leafless plants is the common blackwood (18: 2) as already explained.

The sheoak, *Casuarina* (18: 6, 6^1), is a plant probably accustomed to working in short intervals during and following rain. For the remainder of the year, the weather may be dry. Pull one branchlet (6^1) apart; it is in joints like a fishing-rod. Round the edge of each little socket is a row of "teeth," the much-reduced leaves. The branchlets function as leaves, as in the broom (18: 4) and other switch plants. They are grooved. It has been suggested that a film forms across and keeps water from getting into the grooves where the pores are placed.

E. Spines, Thorns, Prickles and Hairs.

A study somewhat related to water-saving in plants is provided by spines, thorns, prickles and hairs.

The thorns of hawthorn (19: 1), boxthorn (19: 2), and gorse (19: 3) can be regarded as examples of natural pruning; the leafy shoot, being shortened, has fewer leaves and

PLATE 19.—SPINES, THORNS, PRICKLES AND HAIRS.

therefore reduced leaf surface to meet drought conditions. The thorny stunted shoot has probably come into existence under the same conditions as the thick fleshy leaf.

The thorns form further an efficient protection against the grazing animals—an occasional enemy—but drought is the frequently-recurring, all-powerful enemy. Boxthorns in good seasons produce larger leaves and fewer thorns.

On the barberry plant (19:4), a passage may be seen from a full leaf down to the branched spines representing the main ribs of a reduced leaf. The Apple of Sodom (19:5) has leaves much divided and very prickly. This introduced African plant, often wrongly called the kangaroo apple, is spreading even into the remote parts of the state. The apple is "bitter and poisonous." The plant is a member of the potato and tomato family. Robinia (19:6), called in America the "Acacia locust," has the stipules of the large compound leaves, sharp spines which persist on the tree long after the leaf has disappeared. The holly leaf (19:7) has the ends of the main ribs long and spiny. The gooseberry (19:8) has leaf-stalk spines. The leaf of the spear thistle (19:9) has troublesome sharp spines.

Cactus plants, including the prickly pear (19:10) have spines which are sometimes stated to be reduced leaf structures. Rose (19:11) and blackberry (19:12) have down curved prickles easily pushed off from the side. These are primarily climbing organs, not protective structure, though secondarily they may render good service as such.

Hairs (17:10) are a protection from drought, by reducing loss of water; they also help in wet weather to increase transpiration by keeping the surface from being covered by a water film. They serve as a protection from grazing animals by rendering hairy leaves unpleasant in the mouth. Stinging hairs (13:8; 19:13; 67:5) on the nettle are really flasks of formic acid. The slightest touch breaks the sharp, brittle point from the hair. This is embedded in the flesh, and the acid enters, causing irritation. A firm grasp bends the hairs down, and they don't enter the flesh.

F. THE FALL OF THE LEAF.

The days are shortening, the sun rises less high in the sky at midday, the loss of heat at night exceeds the gain by day, and the activity of the plant is checked. The leaf can

no longer work as before. Cold-blooded ("variable temperature") animals become torpid, and many plants become torpid also. The leaf has finished its year's work, and its presence would be a disadvantage to the plant.

The question is:—Why does the plant shed its leaves? It has been established that leaves give off much water. If the supply of water cannot be maintained, the leaf is doing harm to the plant. If there is, periodically, a season when water is scarce, it is an advantage to many plants to lose their leaves. In Northern Australia and other tropical countries, there are trees that shed their leaves every dry season. The silky oak, evergreen in Victoria, is deciduous in Queensland. Cold also prevents a tree from taking in the requisite supply of water. Leaves are now a disadvantage. It is better to shed them with as little loss as possible.

Put a flask on a leaf that is changing color (20: $1e^1$). It does not give off water; "autumn leaves" give off no water (20: 1), nor do autumn leaves contain starch (20: 2).

Water is the great factor in plant life; it is really a question of water that controls the fall of the leaf. The arrangements for getting rid of the leaf are as perfect as the leaf itself was as a food-producer. Everything of use in the leaf is removed, and stored in other parts of the plant. The leaf now is a dead skeleton. The waste products of living matter in performing life processes are left in the leaf as yellow granules, giving the usual yellow color to dead leaves. This is the plant's opportunity to get rid of any injurious matter taken in by the roots. Sometimes the yellow granules are not abundant, and the leaves are a dirty, yellowish white, soon turning brown. At other times, a definite coloring matter is formed, and, just as litmus changes color (20: 3) in the presence of acid or alkali, so this delicate coloring matter becomes red when acid is present, violet when there is little acid, and blue when alkali is present. The yellow with the red gives orange, and the marvellous autumn colors are produced. The brilliant coloring lasts for a short period. Kerner, in his monumental *Natural History of Plants,* has described the Rhine and Danube forests, and the Canadian lake forests in autumn, as scenes of "entrancing beauty."

The food having been removed, the next point is "how" the leaf falls. It is desirable that it should not be roughly

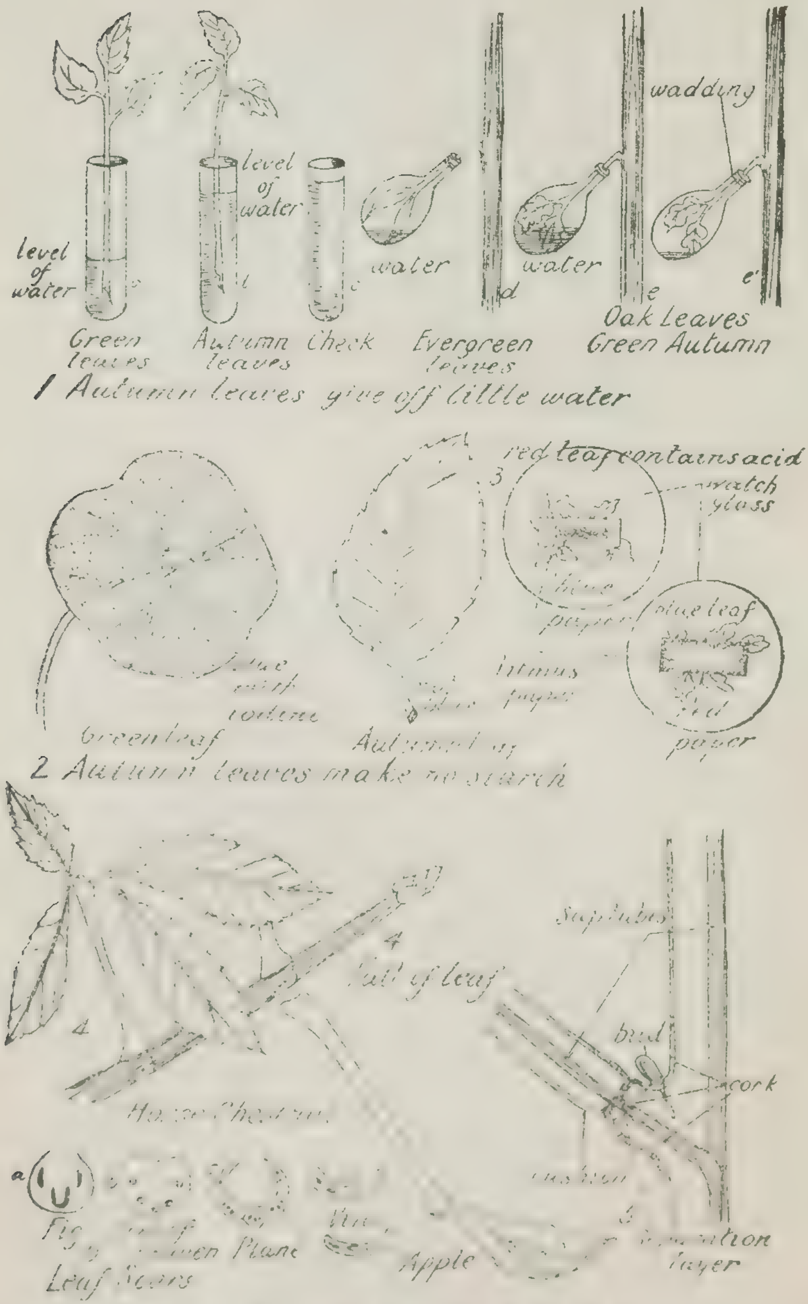

PLATE 20.—THE FALL OF THE LEAF.

1, Autumn Leaves Give Off Little Water, 2. Autumn Leaves Make no Starch; 3, Red Leaves Contain Acid; 4 Fall of Compound Leaf; 5. The Separation Layer, 6 Leaf Scars.

detached, creating a wound and injuring the plant. It is separated without injury. Again, when the leaves are separated, it is desirable that some should fall close to the tree, so that, when they decay, they will enrich the soil.

At the base of the leaf-stalk (12: 1; 20: 5) is the swollen "cushion." Examination of many leaves shows that leaves separate at this place. Note the "scar" on the plant where the leaf breaks off. See in the "scar" the vessels for carrying sap. Some plants have characteristic "scars" (20: 6).

When the time to prepare for the fall has arrived, a definite separation layer (20: 5) forms across the base of the leaf. Soon this layer of cells divides into three rows of flattened cells. The middle row becomes jelly-like and devoid of strength. The sap tubes are now holding the leaf on. A corky layer has been forming below the separation layer; this gradually pinches the sap vessels until they snap. The upper and lower rows of the jelly-like cells absorb moisture and press against each other, helping to snap the sap vessels and push the leaf off. Hence, even when there is no wind, the leaf can be separated, to fall gently to the ground. Here it is buried by earthworms or in some other way, and soon decays. The food particles of which it is composed are again available for use.

The impervious corky layer is completed across the sap vessels, and no wound is left. In compound leaves, such as those of the tree of Heaven (*Ailanthus*) and the horse chestnut (20: 4), the leaflets are shed, and then the long leaf-stalk and midrib.

In evergreens, the leaves last two years or more, and are replaced a few at a time, so that the tree is not bare at any time. It is sometimes said that deciduous trees change their habits in a warmer climate. Oaks and elms in streets and parks in Southern Australia lose many leaves in dry summers, and burst into leaf again in autumn, but there is frost enough to remind them of their original winter habits. In lands devoid of frost, deciduous trees seem to lose their sense of seasons. They become evergreen, flowering and fruiting in a most irregular manner.

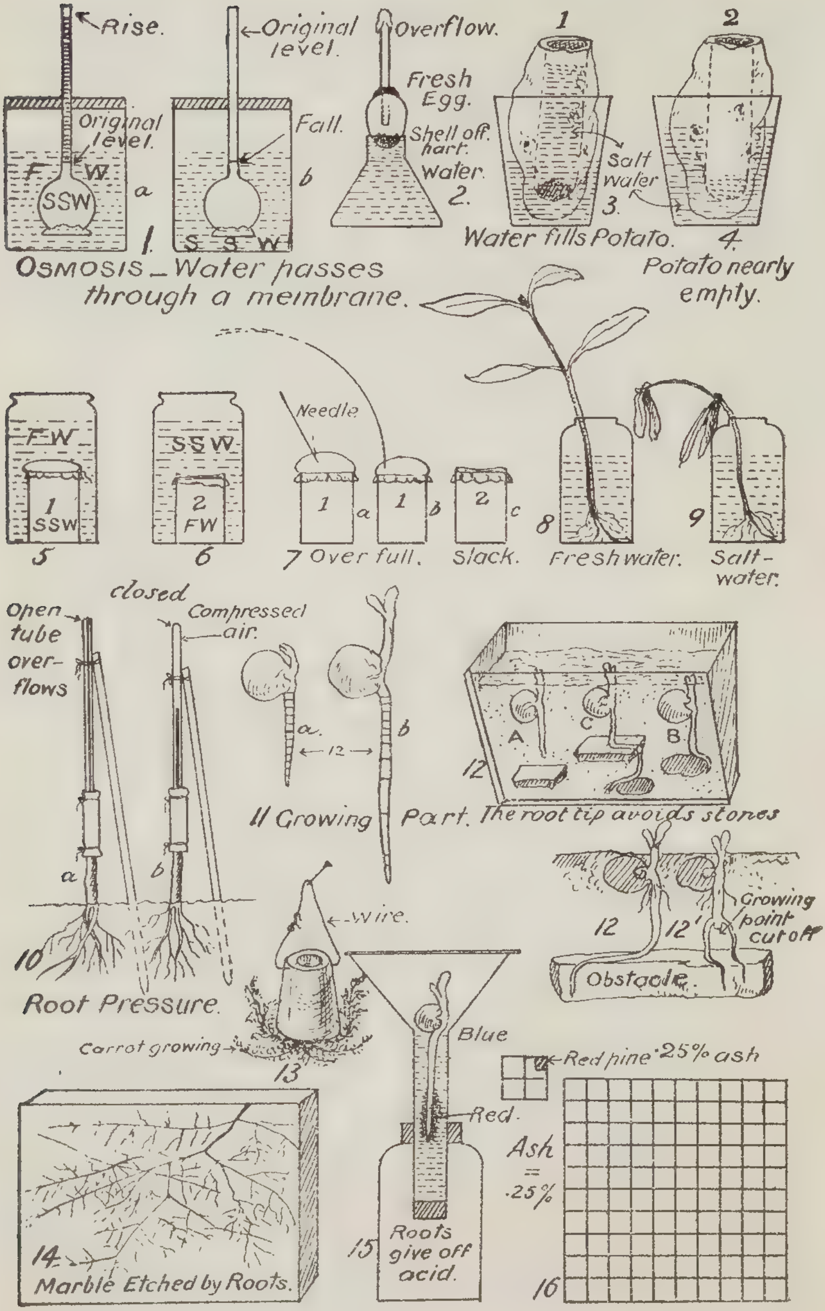

PLATE 21.—SOME ROOT STUDIES.

1, 5, 6. S.S.W., Strong Saltwater; F.W., Freshwater.

CHAPTER V.

THE ROOT.

The root gets water with some dissolved soil substances. If a tree is burnt until no black remains, the ash represents almost all the plant obtained from the soil. Some soil-derived matter, ammonia, for example, being volatile, has escaped. In a piece of red pine that was weighed and burnt the ash equalled only .25 per cent.; one part in 400 (21:16). The soil material is necessary for the plant's existence. The main elements required are nitrogen, phosphorus, and minute quantities of potassium, sulphur, iron, and other elements.

The plant's drinking water is as pure as our drinking water; that is, there is little dissolved material in it. To show there is material dissolved in clean tap water, evaporate some on a clean thin glass (189: 1c). The outline of the drop remains as a stain of material dissolved in the water.

Much water is required to supply enough soil material. It has been calculated that, for every pound of dry matter in a plant, it has used over 300 lbs. (30 gallons) of water. This water is liberated as water vapor. The leaf is not perspiring when losing it, but is "transpiring." The current of water rising to the leaf is the "transpiration current." We can call the ascending liquid "root-sap"—water with some good soil dissolved in it. Consider how the water enters the root. One common idea is, "The root has a mouth at the end." Draw the pea seed with the first root growing down towards a big stone (21: 12, 12^1). "What will the root do?" "It will grow round the stone." Suppose there is good soil close by. "The root will perhaps find it." The growing point has been called the "brain" of the plant. Our brain is protected by a bony skull. This brain is protected by a cap of cells—the root-cap (22: 10, 12, 13). Compare it with a muzzle, sometimes seen on a dog or a horse. Even if there is a mouth at the end, it is useless—there is a muzzle over it. Children next suggest that water gets in through mouths on the sides. When a mouth is opened, would water run in or out?" From their experience of a broken root

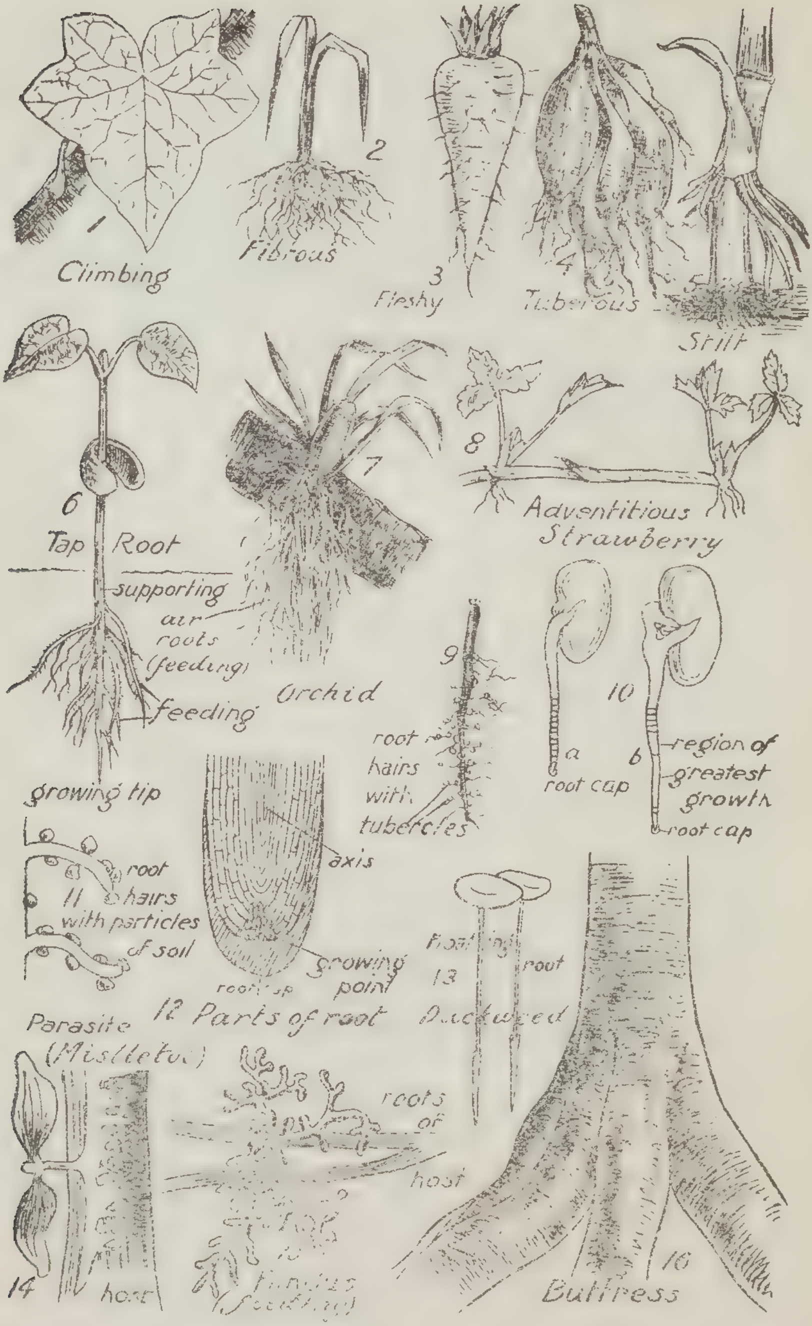

PLATE 22.—SOME ROOT STUDIES.

they answer "out." A mouth would be useless. How can water get in? Let us answer this by an experiment.

A few days before, a potato was scooped out (osmosis experiment—21 : 3). Some salt was put into it, and it was placed upright in fresh water. On examining it now, the potato contains water. How did the water get in? At the same time, another potato, filled with fresh water, was placed in a vessel containing strong salt water (21 : 4). This potato is nearly empty. How did the water leave it? Two other osmosis experiments assist in illustrating this point. In 21 : 1a fresh water passes through the parchment paper and rises in the tube. In 21 : 1b fresh water leaves the tube through the parchment paper. 21 : 5 works as 21 : 1a, and 21 : 6 as 21 : 1b. The pressure of the liquid in 21 : 7 filled as in 21 : 5 caused a jet to squirt out when pricked.

Water similarly passes into the root. To increase the surface, the cells on the sides form processes (22 : 11; 56 : 6c-e). The processes of wheat and radish roots are small and crowded together, giving a fluffy or hairy appearance; they are called "root hairs." They are skin bags, not hairs; and are found only where the skin is thin, some little distance from the growing point. They absorb water, and often grow firmly to soil particles (22 : 11), helping to fix the plant. Later, the skin becomes too thick for water to pass through. The thick parts of the root support the plant (22 : 6), and may also be a store of food in carrot (21 : 13) and other plants. Plants grow without soil if supplied with proper water, root food, and the necessary air.

To discover the regions of greatest growth, mark some roots and stems of germinating peas and beans with Indian ink at equal intervals (21 : 11). Examine them a few days later. The divisions on the stems elongate at approximately equal rates, but roots grow near the "growing point" (22 : 10).

Root pressure is easily shown (21 : 10). Cut off a vigorous marsh-mallow plant a few inches above ground. Fix to it, by a rubber tube, an open glass tube. The water will often overflow. A variation is to use a closed tube. The pressure of the water driven up will sometimes force the contained air into less than half its original volume.

Manure must not be too freely supplied. If the external solutions are strong, water (21 : 8, 9) may be abstracted

from the plant which wilts or withers, as does a seedling in strong salt water, whereas one in tap water remains fresh. Carbon dioxide from the breathing of roots is an acid and dissolves substances insoluble in water. A seedling root (21 : 15) growing in jelly, colored blue by litmus, will cause the red color denoting an acid. Acid from roots has also etched smooth marble (21 : 14).

A variation of the osmosis experiment is to bore a hole in an egg (21 : 2) and insert a short glass tube held in position with plasticine. Then chip the hard shell carefully off the other end. Stand the egg on a bottle of water. Water enters the egg and liquid soon overflows.

Roots live under many different conditions and vary greatly in form. Some plants have a long tap-root growing down (22 : 6); others, like grasses, have many fibrous roots (22 : 2); others have fleshy roots (22 :3) serving to store food in addition to the general functions. The tuberous roots (22 :4) of the Dahlia have similar functions. The tall growing maize (22 :5), to gain extra support, has stilt roots growing down to the soil. Buttress roots (22 : 16) of giant eucalypts and Moreton Bay figs (22 : 16) act similarly. Strawberry runners and many grasses have adventitious roots (22 :8), assisting in spreading the plant.

In damp forests, certain orchids, for example (22 : 7) can grow on the side of other plants, or on rock faces without soil. Such "epiphytes" have spongy absorbing aërial roots, and obtain all their water and nourishment from the air; epiphytes are not parasites. The mistletoe (22 : 14; 29 : 4), a parasite, is rooted into the host.

Two interesting cases of partnership may be mentioned. Leguminous plants have "nodules" (22 : 9; 49 : 1) on the roots, containing bacteria which can "fix" the nitrogen of the air. The pea plant helps the bacteria by supplying some of their food. The bacteria help the plant by supplying nitrogen in usable form. The bacteria from leguminous plants cannot be used to increase fertility for other plants, nor can the bacteria of one legume be used for a different kind. Some plants have no root hairs, and live in partnership with a fungus (22 : 15). The fungus, forming a growth over the rootlets of the plant, absorbs water. It supplies water and soil food to the host which gives it leaf food.

CHAPTER VI.

THE STEM.

Stems serve mainly to support and spread the leaves to the light and air. They act as a go-between for leaf and root, taking the root-sap to the leaf to be made into food, and conducting the food-sap from the leaf to the parts that need nourishment or store up food.

Stems vary in size and shape. In some of the ground plants, *e.g.*, dandelion, the stem is a flat, button-like structure, from which the roots grow down and the leaves grow up. In other plants, the stem is long, and branches much. If trees are crowded, there is a struggle for light, and the stem is enormously developed, as each tree strives to get above its neighbors. In the Otway and Gippsland forests, stems often measure up to 150 feet without a branch. Where trees are less crowded, they are wide-spreading. The leaves grow all around, and each gets plenty of light.

Experiments have already shown that leaves give off much water. How does water get to the leaf? Place variout twigs, *e.g.*, grape-vine, apple, cherry, Geranium, daffodil, upright in dilute red ink. Soon the flowers and stems will be marked with red. Cut them across. Red dots are definitely arranged in the apple, cherry, Geranium, and vine-cutting; water runs up in definite channels. Split the Geranium stem lengthwise, and note the sap vessels arranged in a ring. In a grass stem, bracken fern (54:1[1]) palm (24:4) or Arum stalk, they are not so regularly arranged.

Choose a fairly old branch (23:18a) which has at least three twigs. Ring the left twig by cutting into the wood all around; cut a strip of bark about an inch wide from the right twig; leave the central twig as a control or check. No. 1 soon dies; No. 2 grows even more vigorously; No. 3 grows slightly. No. 1 dies because it cannot obtain water, the water tubes having been cut. No. 2 grows vigorously because its manufactured food material is being used within the branch, and produces more vigorous growth. The reason for the bark ringing ("cincturing") of raisin vines,

and the consequent improvement in the fruit will now be evident: the "cincture" is not a permanent ring; it is soon healed up, and, meanwhile, the food manufactured in the branch has gone into the grapes.

How does the food-sap travel down? Not through the center of the stem, since it can come down when there is no

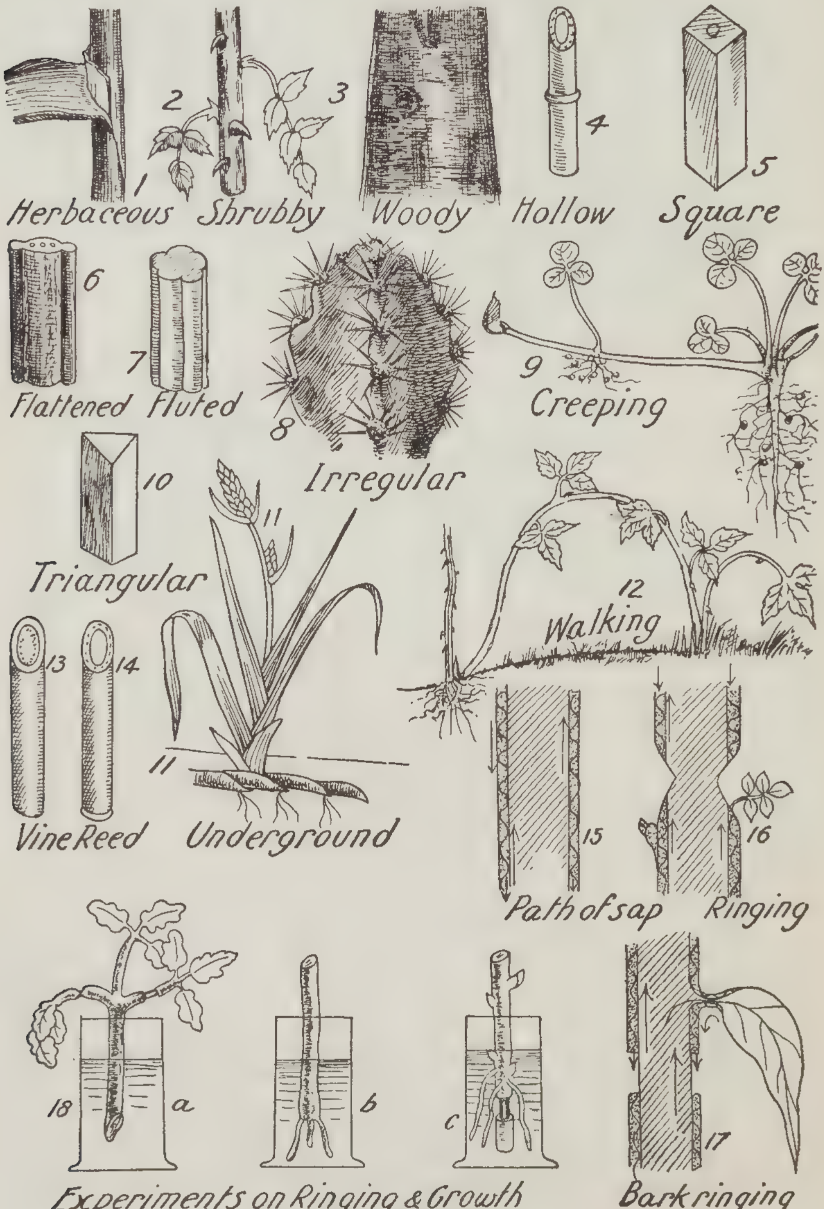

PLATE 23.—STEM STUDIES.

1-14, Kinds of Stem; 15-17, Path of Sap; 18, Experiments on Ringing.

center, as in grass, reed, bamboo, or a hollow tree. Get two leafy willow twigs. Take a ring of bark an inch wide near the end of one; stand both in water (23: 18 b, c). After a few days, examine them. Rootlets are growing from the end of twig *b*, and from the upper part of the barked ring *c*. The food-sap runs down the inner bark. In a large tree, the sap runs up in the outer part of the wood (23: 15), and down in the inner part of the bark. Between the bark and the sap-wood is the wonderful "growing ring"—the cambium (24: 2), which constantly produces new cells—those on the inside to form fresh wood and vessels to conduct water to the leaves, and those on the outer side to form more soft bark and to conduct the food-sap down from the leaf. These cambium ring cells divide quickly when there is warmth and moisture. In a period of cold or scarcity of water, they divide slowly; they are thick-walled and small, instead of being large and thin-walled, as they are in favorable times. Looking at a tree-stump (24: 1) one sees the result of favorable and unfavorable times in the rings of large thin-walled vessels or small thick-walled vessels. Since, in many countries, there is one unfavorable period for growth each year, it is possible to tell the age of a tree (24: 3a-c) by counting these rings. In Australia, in many years, there are two periods favorable for growth, spring and autumn; it is, therefore, possible to have more than one ring formed in a year, and the age of the tree cannot be directly inferred from the number of rings.

A forest tree grows by adding to the outside. The original soft center of the young stem—the pith—is crowded and crushed, the inner vessels become filled with woody material, and water no longer travels along the "heart-wood." The "rays," or "silver grain" (24: 1), run outwards; some run from the outside into the sap-wood, some to the heart-wood, and a few even to the pith. Food and air travel along these "rays" to the inner living parts.

While the circulation of root-sap to the leaf, and food-sap from the leaf, is somewhat analogous to the circulation of the blood, there is one important difference. We have arterial blood bearing food and air to each part, and venous blood bearing waste products to the lungs. It is not so in the tree; there is no waste-product current—no blood being

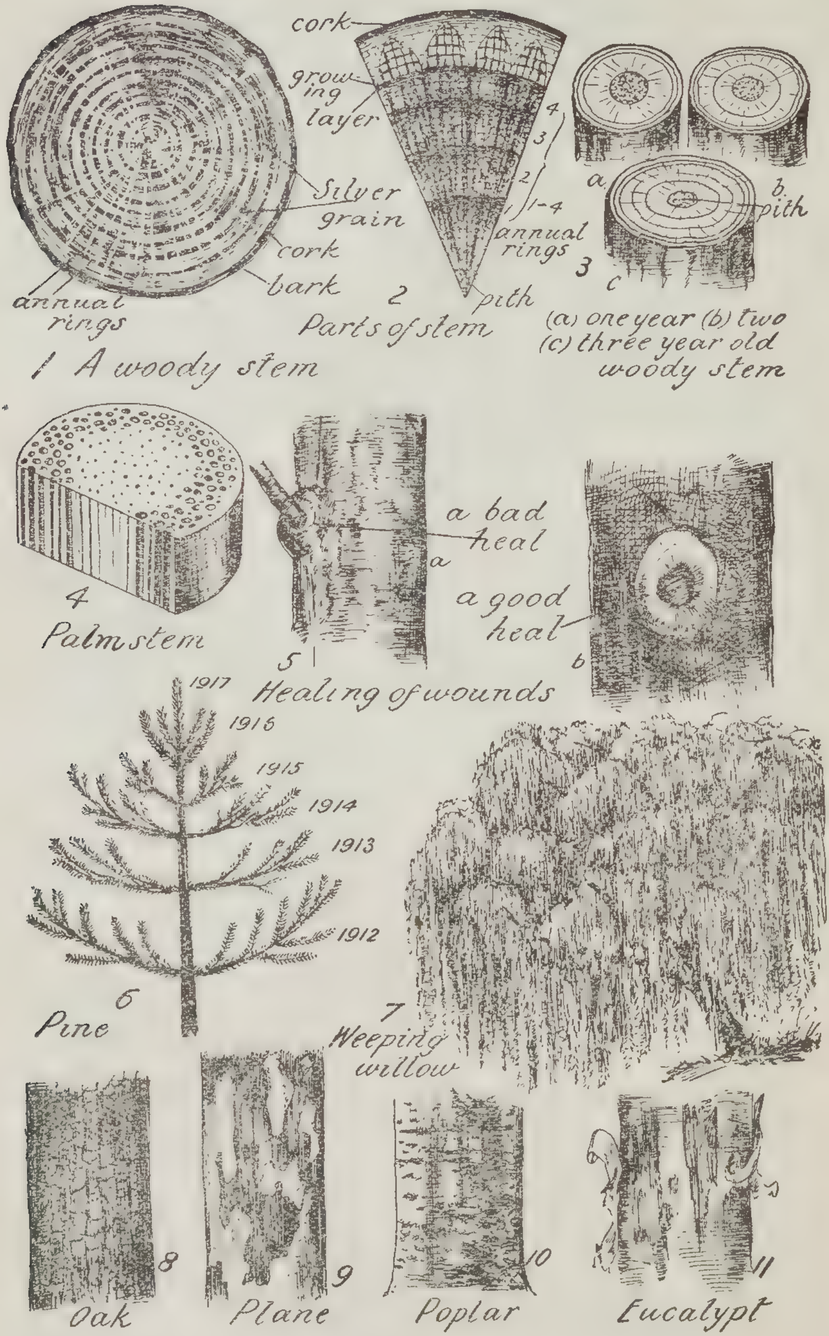

PLATE 24.—SOME STEM STUDIES.

1-3, Annual Rings; 4, A Palm Stem; 5, a, b, Healing of Wounds; 6, 7, Tree Studies; 8-11, Barks.

sent to the lungs to get rid of waste. Each plant-cell breathes for itself. Though there are two currents, one is of water and dissolved substances to the leaf, and the other is the food current along the inner bark and rays to the living parts. The effect of "ringing" a tree will now be seen. Two methods of ringing are commonly followed. (1) A narrow ring is cut through the bark (23:16), the wonderful growing ring, and the sap-wood. The vessels carrying water to the leaves are cut. The top dies almost at once. Food is stored in the root, as in other parts, and the plant endeavors to repair the damage by sending out suckers below the ring. If these suckers develop leaves, the root has "kitchens" and does not die. To kill the root by this method, the suckers must be checked.

In the second method, a broad band of bark (23:17) is removed, care being taken not to cut the sap-wood. Water now ascends to the leaf. The leaf manufactures food, and sends it down, but none crosses the ring (about a foot in width), and the root, when it has used its reserves of food, dies. Often extra growth can be seen just above the ring, which, if narrow, is sometimes filled up. When the root dies, the top dies also. This method is surer though it is slower. A tree treated by the first method shows immediate results, but may not be killed. Many paddocks, once rung, are now seven times worse than in the first state, the suckers being almost as big as ordinary trees. A tree treated by the second method may show no change for several weeks. A modern method is to make a ring of cuts and inject poison.

There are at least two sources of wonder in connexion with the stem. The first is how the stem supports the great weight and withstands the pressure of storms and winds; and the second how the sap rises.

First, compare a stem with any work of man. A tall structure, such as a furnace chimney, tapers to the top, and, as a rule, has a height not more than 17 times the diameter. Compare this with a wheat straw. Here the height may be 500 times the diameter, and the weight is at the top. A large branching tree resembles an inverted pyramid. Water plays a large part in the rigidity of the stem. Place a drooping flower in water; it becomes upright and fresh. Each cell is filled with water; the plant is stiffened with water. Compare a half-blown-up football with an inflated one.

Secondly, let us consider how the sap rises. A large tree has been calculated to give off about 90 gallons of water a day. How is that amount of water sent up to the leaves? Moreover, it has been shown that there is great resistance to be overcome, so that it is not merely a question of pumping the water a great height in a forest giant. Dr. Ewart, Professor of Botany in the University of Melbourne, has shown that the total pressure required to maintain active transpiration in the tallest trees may be equivalent to as much as 100 atmospheres (1475 lbs. to the square inch). What causes the sap to rise against the great resistance?

Root pressure (21 : 10) has been suggested, but it has been shown that the maximum root pressure seldom reaches much beyond the pressure of one atmosphere (34 feet of water); a pressure of about 40 feet of water has been recorded. But root pressure varies, and, when transpiration is most active, root pressure may be negative. Yet the root-sap is reaching the leaves. It is also known that the current continues in plants in which the roots have been killed; the rise of sap cannot depend on root pressure. It was suggested that living matter in the cells controlled the ascent of water. The living matter was killed, yet water ascended. Capillarity was suggested, but sap could not rise in a tree 200 feet high by this means. Sap rises in some trees where there are no open continuous spaces or tubes. Even if the sap could rise by capillarity, that is too slow a process to supply enough water. It was suggested that perhaps the water rose in the trees as a vapor; that would leave the soluble plant food in the root, whereas it is wanted in the leaf.

Osmosis has been suggested, but Vines found that the suction force of a transpiring branch was never greater than two-thirds of an atmosphere. Osmosis cannot account for the ascent of water in a big tree against a great resistance. It would also be too slow. Some have said that the loss of water in the leaf gives rise to a vacuum, and the atmosphere then forces water up. Even if a total vacuum were formed, the atmosphere supports only 34 feet of water; this cannot explain a rise of 200 feet.

We are driven to Strasburger's conclusion, namely, that "All efforts to determine the cause of the ascent of water have been fruitless, and that all previous explanations are untenable." The stem of the tree, therefore, presents an unsolved, but fascinating, problem. Many scientists are at work experimenting and investigating, in the hope of adding further to human knowledge by solving this mystery.

Stems present great variety. Grasses have herbaceous stems (23: 1), roses have shrubby stems (23: 2), and most trees have woody stems (23: 3). Some stems are hollow (23: 4), some have a pithy center, and some a center of dense "heart-wood." Most are round, some are square (broad bean), some (23: 6) are flattened (sweet pea), some (23: 7) are fluted (blackberry), and some triangular. The cactus has an irregular stem that may be globular, as in the vegetable hedgehog (23: 8). The creeping stems of clover (23: 9), arching stems of blackberry (23: 12) and the underground stem of bracken (54: 1) and sedge (23: 11) assist in spreading the plant to new places,

Branches have often a definite arrangement. Pines (24: 6) produce one circle (whorl) of branches each year. The weeping willow (24: 7) has a drooping habit.

Stems are protected by bark, which varies greatly. The persistent bark of the oak (24: 8) gives a characteristic rugged appearance. The plane (25: 9) sheds its bark in irregular pieces. The poplar (24: 10) has clean branches, though the old trunk becomes rough with persistent bark. Eucalypts vary; ironbarks retain the bark until it is several inches thick; blue gums drop the bark in very long ribbons. Lemon-scented gums (24: 11) peel off the bark in small pieces and retain a beautiful clean bole. "Stringy bark" has a persistent bark; when removed in large sheets, these are valuable as a roofing and building material.

When a branch is cut off or pruned, the tree tries to heal the wound (24: 5a, b) and prevent the entrance of bacteria and fungi. Bad pruning causes trouble later.

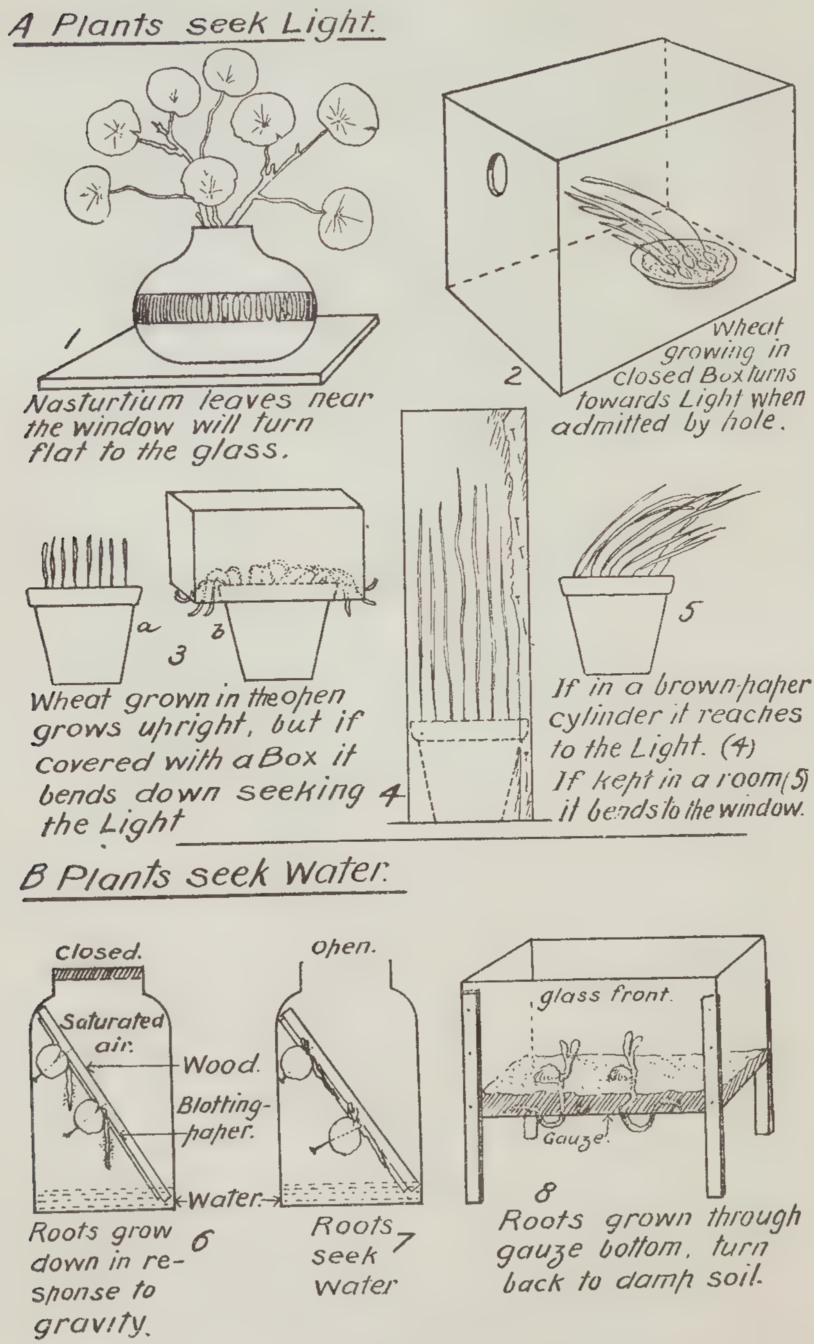

PLATE 25.—PLANTS FEEL—THEY RESPOND TO THE STIMULUS OF LIGHT, WATER, AND GRAVITY.

CHAPTER VII.

PLANTS FEEL.

It has been shown that leaves require light. To prove that leaves respond to the stimulus of light, wheat seedlings may be grown as in experiments (25:2-5). Place a leafy spray of the garden nasturtium or Indian cress (*Tropaeolum*) (25:1) in water near the window. The back of each leaf should be turned to the light. By next day, each leaf has turned over to face the light. Inspect garden plants and note that each leaf is so placed that it can get light. Notice also that one leaf is not entirely hidden by another. If a leaf is almost hidden at one time, it may obtain a satisfactory amount of light at another period of the day. The leaves of the marsh-mallow follow the sun all day. Roots avoid light and also show response to the attraction of gravity. In physics lessons, doubtless many learned that gravitation, unlike magnetism, is not a selective force—that is, it attracts all bodies equally, whatever the material. Experiments in plant life show that gravity attracts roots and repels stems (26:3-5). Roots grow down in virtue of the attraction of gravity. Plant half a dozen peas or other seeds in different positions. The little roots always turn down as soon as possible. Place one seed behind a glass front in the middle of a cardboard box full of soil (26:2). Stand the box on one side. When the root is nicely started down, stand the box on the next side for two or three days. The root grows down; again turn the box, the root again turns. A variation is shown in 26:2[1] with pea seeds on a hat-pin in a damp bottle. See if you can make a root grow completely round twice. It is a simple but striking experiment. Take three seedlings, cut off the growing tip of the root of one of them (26:6); fasten them horizontally. The cut root grows straight on until a new tip forms; the others bend down and the tips grow down.

When a growing plant is fastened on a slowly rotating wheel, gravity is equalized; the root grows in whatever position it is placed. Fasten peas on a slowly revolving

cylinder, so that gravity is equalized (26: 1). The roots do not grow down. If a horizontal wheel is rotating rapidly, so that the centrifugal force preponderates over gravity, the roots grow outwards in a slanting position due to the resultant of these two forces. On a rapidly-rotating

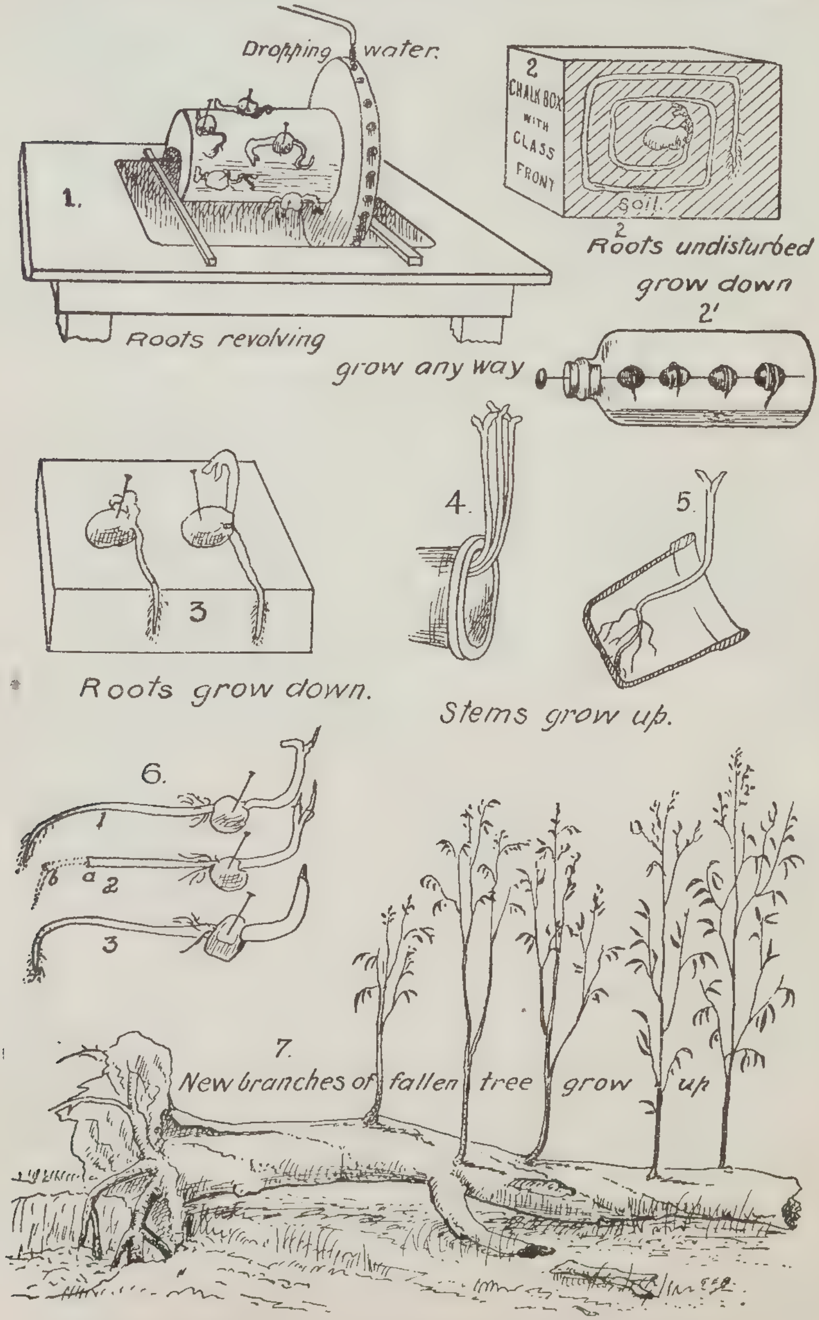

PLATE 26.—PLANTS FEEL—ROOTS GROW DOWNWARD, STEMS GROW UPWARD.

vertical wheel, where gravity is equalized the roots all grow out in response to the centrifugal force.

Stems, influenced by gravity, grow upwards (26: 3-7). The quickness of the response is often surprising. Take a

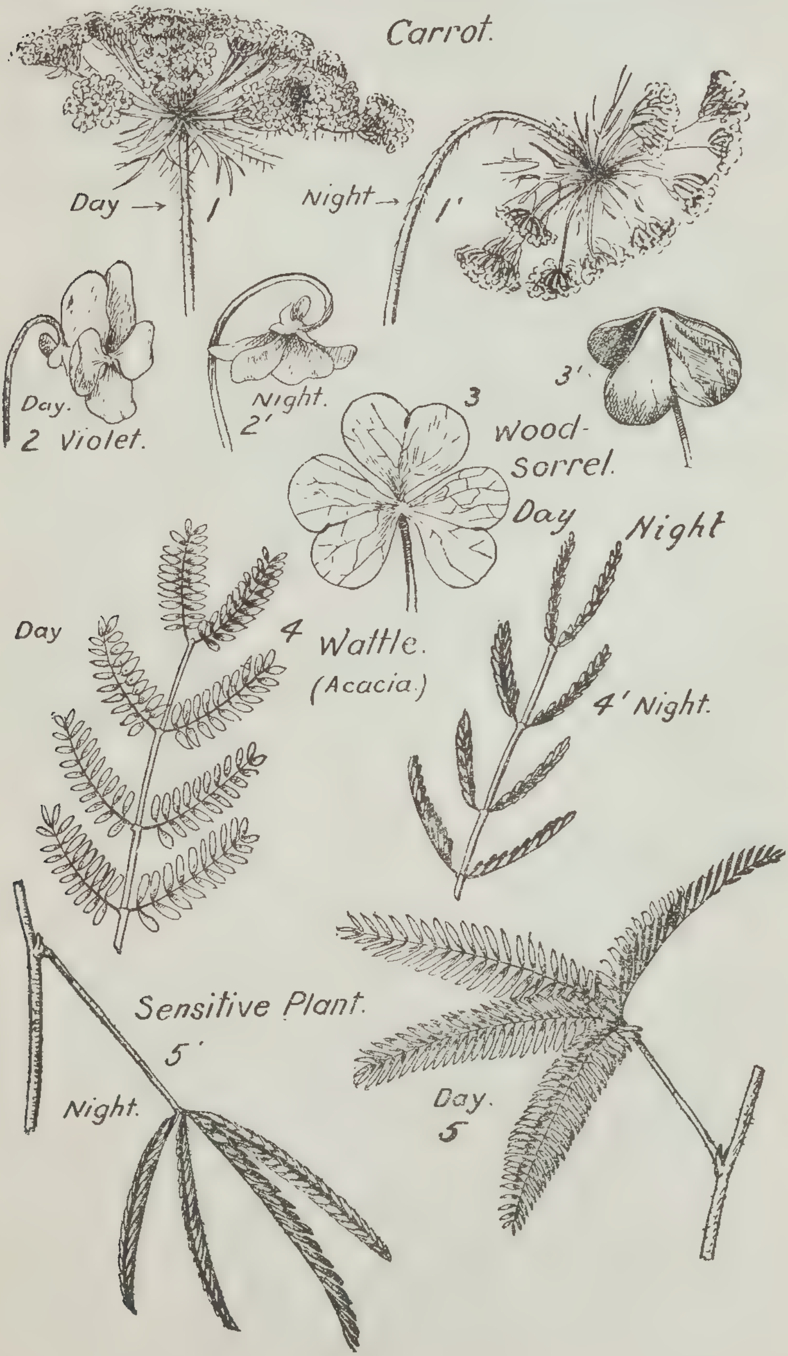

PLATE 27.—SLEEP OF PLANTS.

developing seedling of maize grown in the vertical position; place it in a horizontal position (26: 6^3). Very soon the tip of the root turns down and the stem turns upward. The branches of a fallen tree (26:7) grow vertically upwards.

In addition to light and gravity, water also exerts an influence on plants, so that some plants seek water (25: 6-8). The following experiment will show this:—In a jar which is sealed (25: 6), the air is saturated with watery vapor so that no attraction in any particular direction is exerted by water. The root follows the attraction of gravity and grows straight down. In the second jar (25: 7), which is open, the water is coming up the blotting-paper to the seeds, and the root, seeking water, instead of growing straight down in response to gravity, grows down along the blotting-paper, which is four-fold on the piece of wood; the air in this case was not saturated with water.

Again, roots, after descending some distance, have returned to the damp soil or wadding in response to the attraction of water (25: 8). No nerve-cell has been detected in plants, but they are very sensitive, and soon respond.

One of the most interesting examples of plant response is furnished by the "sensitive plant," a species of *Acacia* (27: 5, 5^1). The leaves resemble those of the feathery-leaved wattles. If a leaf is touched, it closes. If a match is struck near the plant, the leaves fold down.

Wattles (27: 4), Robinias (61: 2), clovers (32: 6), wood-sorrel (27: 3), and others fold their leaves at night. Many flowers close or droop at night (27: 1, 2; 43: 1-7).

CHAPTER VIII

CLIMBING PLANTS.

Finger-like processes have appeared at the ends of the leaves of the pea plant. Why should they be there? What purpose do they serve? Some days later, it has been discovered that they assist in supporting the plant; all are now ready to study climbing plants. If children understand why and how one plant climbs, they will discover how the plants of the district climb. Since the peas of the vegetable garden are being selected rather on the dwarf side, they are losing

their climbing powers, and the sweet-pea plant may be studied instead as a climber (28:7).

Plants need air, food, water and warmth. Air is obtained readily without special structures. Warmth is given by the sun. Food and water, as already shown, are obtained by root and leaf. To ensure success, most plants have many leaves, and to support these leaves is not an easy matter. If there are many leaves, the plant must have a big or, at least, a long stem, which is usually strong. To make it strong takes time, food material, and energy. Any plant that leans on, or clings to, a foreign support saves material, energy, and time. To utilize a support is an obvious benefit to the plant. Blackberries and roses often scramble over ledges, fences and other supports. Growing up through narrow spaces and putting out branches, they support themselves. They have also down-curved prickles (19: 11; 28: 10), and are not easily pulled down. The prickles are regarded not as protective, but as climbing structures. If the blackberry shoot does not find support, it droops to the ground. The end gives out roots (23:12), and an arch is produced rooted at both ends. The next branch supports itself against this arch. In time, a tangle of interlacing arches is produced. Blackberry plants present many leaves to the light, and are successful in the struggle for existence. 'Arching" and "scrambling" are good modes of climbing.

The French Bean (scarlet runner) twines closely round a support. The tip on a calm day will be seen to travel slowly in a circle, seeking for support. If it touches anything, it rests close against the foreign body, and the tip circles round it. If no support is near, the twining plant falls to the ground, but it does not give up the struggle. It grows longer, and the tip again circles round. If it finds a suitable object, it twines round it; but, if it cannot find support, it seems to sicken, and dies.

Some twining tips (28: 8, 9) move in the same direction as the hands of a clock. Others move anti-clockwise. You cannot get one to reverse its proper direction. It is difficult to get a twiner to climb round a horizontal support; it wants to get up. Observe the time taken by different twining tips to complete one revolution. Make a list of right-handed twiners and left-hand twiners. Twiners produce a great

length of stem, which is not used directly in a vertical direction. Convolvulus (28: 8) and hop (28: 9) are twiners.

The sweet-pea (28: 7) grape-vine (63: 2), passion fruit, pumpkin (28: 5), and others have special clasping tendrils supporting the stem. The plant produces many tendrils to

PLATE 28.—CLIMBING PLANTS.

ensure that enough to support it are gripping foreign bodies. This is a successful method of climbing. As soon as the sensitive tendril touches anything, it grows round it.

In the pumpkin (28: 5; 64: 3[1]) and others, the tendrils coil in one direction for half their length, and in the reverse direction for the other half. In a storm, the tendril acts as a spring, allowing the branch to be pulled out some distance, and returned to its original position, without risk of losing its hold. In the Virginia (28: 2) and Japanese (28: 3) creepers, the hand-shaped tendrils terminate in suckers that cling to the walls of houses, and these plants have in autumn a beautiful mass of rich, variously colored autumn leaves.

Many parts of a plant are modified into holding organs. In the traveller's joy, or Clematis (14: 15), and the garden nasturtium (28: 4), a long leaf stalk grows round a support, and holds up the plant. These are "leaf-stalk" climbers. In the sweet-pea, the tendril is a modified leaflet; the compound leaf (28: 7; 15: 19) has some flat leaflets, and the rest tendrils. In Smilax (28: 6) the stipules are modified into effective tendrils.

Another method of climbing is shown by the ivy (28: 11), which produces two kinds of roots—the ordinary absorbing roots underground, and non-absorbing climbing roots (22: 1) on the stem, mostly on the side near the support. These "aërial roots," devoid of root-hairs, are climbing organs. Ivy, though it smothers trees, is not a parasite.

CHAPTER IX.

PARASITES.

Dodder (29: 1), is a parasite. The seed develops on the ground, the young plant twines round another plant and obtains food from its support by means of suckers along the stem. The part connected with the ground dies off, so that dodder is entirely dependent on the host for food. It is a serious pest. Different kinds growing on many plants use up the food of their hosts and prevent seed formation.

Mistletoe (29: 4 and 22: 14) is a semi-parasite. It robs the tree of water and root food, and, possibly, of some starch. However, it has leaf-green and can manufacture its own leaf-food. The leathery leaves of one kind hang

vertically, "mimicking" eucalypt leaves. The flowers are pollinated by the Australian flower-pecker. The fruit has a leathery skin and a very sticky seed. The flower-pecker drops the leathery fruit skin and reveals its presence.

The extremely sticky seeds adhere readily to the bill and are wiped off on a branch, or are passed by the bird uninjured, and adhere to the branch. Some native ever-

PLATE 29.—PARASITES.

green mistletoes live on deciduous fruit and street trees.

Bartsia (29: 5) is spreading rapidly. In spring the flowers give a purple tinge to acres of pasture land. It is parasitic on grass roots, but manufactures its own starch. It is an introduced member of the snapdragon family. The "native cherry," *Exocarpus,* is also a root parasite. It is often a shapely tree with foliage suggesting that of the cypress.

Many fungi are parasites. Rust (29: 2) and smut (29: 9) are common parasites on cereals and other plants. The brown spots on wheat and marsh-mallow plants are often caused by rusts. The "vegetable caterpillar," *Cordyceps* (29: 8; 114: 1), is a "beneficial" parasite. The spores are taken in by the ground-dwelling larva of a moth. The fungus grows throughout the caterpillar, eating up the tissues until the caterpillar is a mass of fungus material. To scatter the spores, an outgrowth is put up to the surface. Cordyceps of many species are widely spread. "Irish blight" is a fungus most destructive to potato plants in a damp season. A related fungus kills many house flies (29: 7). Several pale flies with a halo round them may occasionally be seen. These have been killed by the fungus. Another fungus kills grasshoppers in great numbers.

To remind us that all parasites are not plants, the flea (29: 6) an external parasite of man and dog, is figured.

Dean Swift's lines are, however, not to be taken too literally :—

Big fleas have little fleas upon their legs to bite 'em;
These again have lesser fleas and so *ad infinitum.*

CHAPTER X.

BUD STUDIES.

Early spring is the time for studying how trees, introduced from colder countries, rapidly take advantage of warmer conditions, and, in a few days, burst into the full glory of flower and leaf. Evergreen trees have, in this winterless climate, expanded their new leaves, some of them weeks ago, but deciduous trees, true to long-inherited habits, are just resuming activity after their winter torpor. Possibly there is no more interesting or beautiful branch of nature-study than that of "bursting buds."

Stand many kinds of pruned twigs in water in a warm room. Some buds will expand leaves and flowers two or three weeks earlier than those in the garden. Trace back a fairly long developing shoot through a series each less developed than the other; see young shoots, four inches, two inches, half-an-inch long, and another bursting from the bud. Remove the covering of this bud, and see the "baby branch" inside. Now take an unexpanded bud. Is there a "branch" in this? Carefully remove the covering, scale by scale, and see the tiny "baby shoot." All is ready for spring warmth, and it is little wonder, that, in a few hours

PLATE 30.—BUD STUDIES.

it almost seems, a bare tree is transformed, and clothed with beautiful, delicate, and soft-tinted leaves. You can even count the number of leaves while the shoot is in the bud.

The bud, then, contains a "baby shoot," which lengthens into a full branch. Next, note the position of the buds. Just outside the bud there is a scar (20:6). What is this? By examining different twigs, it can be discovered that it is the mark left by a fallen leaf. Find the bud in the angle between leaf and branch. Some buds are terminal, they terminate a branch, but lateral buds are mostly in the angle between leaf and stem. An injured plant, *e.g.*, a "lopped" street tree, may produce a bud almost anywhere. The usual place, however, is in the angle between leaf and stem. This is convenient, for, as food is manufactured in the leaf, it can be used to produce the bud at its base. In some plants, the bud is opposite the leaf scar, which is, in them, the most convenient place, because of the placing of the sap tubes.

Inspect the expanding branch again. If it is a plane branch, or a rose branch, it bears leaves, and possibly flowers. Other buds, *e.g.*, peach and apricot, produce flowers only or leaves only. The peach (31:5) usually has three buds together—two fruit buds and one leaf bud. Some apple buds (62:4, 7, 8) have leaves only, and others leaves and flowers. It is important that orchardists should distinguish flower buds, that is, fruit buds, from leaf buds. Fruit buds usually occur on a definite position on the branch in each plant; they are usually stouter and more rounded than leaf buds. Cherry (31:6), plum (31:7), pear (31:1), and apple fruit buds are borne on "old" wood of several years' growth, while peach and apricot (31:2) fruit buds are on "new" wood of the previous season's growth. Open some stout buds and see the flowers in them. Mark on twigs, buds suspected to be fruit buds, and buds thought to be leaf buds; a few days will enable you to decide.

One point of wonder is that there should be room in the bud for the full number of leaves (30:5) and flowers. Consider the perfect manner in which the parts are disposed. The leaves are tucked away beautifully. This is performed in different ways in different plants. Observing and describing how the leaves are arranged is good nature-study. Some have the edges rolled round, in Arum,

fig and Canna; inwards, in violet; and backwards, in dock. Ferns, *e.g.*, bracken (30: 7) have the fronds rolled up lengthwise, like the mainspring of a clock; reddish hairs protect the delicate tissues.

Some leaves, *e.g.*, rhubarb, are crumpled together; others are folded fan-wise. The horse chestnut is bent backwards as well as folded fan-wise; these arrangements enable the parts to fit better in the bud and offer less surface to weather and sun, until the tender leaves have hardened. Though the old leaves of deciduous trees are placed horizontally, leaves freshly emerged from buds are never horizontal; they are too delicate for such exposure. The red color so conspicuous in eucalypts and rose shoots probably serves to protect the young tissues from excessive light; the coloring matter absorbs or reflects excess light and heat.

Severe frosts at this stage cause heavy loss. Favorable weather in early winter may cause many buds to expand, and killing frosts may nip the partly-opened buds.

Other plants have large stipules which protect the bud. Once the shoot has grown past them, they drop off, and may, in beech forests, suggest "autumn" leaves. The buds of the Moreton Bay fig (30: 4) are often two or three inches long. As the tree is an evergreen, these buds are always available for study. Two stipules form "caps," then comes a leaf, then two more stipules, and another leaf, and so on. Often two small flower buds can be seen.

Another point to observe is, which buds expand first, leaf or flower buds? On wind-pollinated trees, *e.g.*, elm (58: 2) flowers (30: 3) develop first, the pollen is dispersed, the green-winged fruits are perfected, and then the leaf buds (30: 3^1) expand; leaves would interfere with pollination.

Usually there are more buds than are necessary for present requirements; some are held in reserve. Remove the bursting buds from a twig; soon some of the "dormant" buds will develop. On the oak, they are said to retain their vitality for centuries. Should a tree be broken in a storm, new shoots appear, possibly from long dormant buds. Dormant buds furnish another example of the remarkable providence shown by plants.

Some buds store food in the leaves forming part of the bud. Cabbage (30: 8) and lettuce have gigantic buds. The

plant works first to store food, then this is used to lengthen the short bud axis, spread the flowers, and perfect the seeds. Onions (50: 11) and lily bulbs (50: 13) are also bud-like, with food stored in the bases of the scale leaves; all is ready in preparation for a vigorous start when favorable condi-

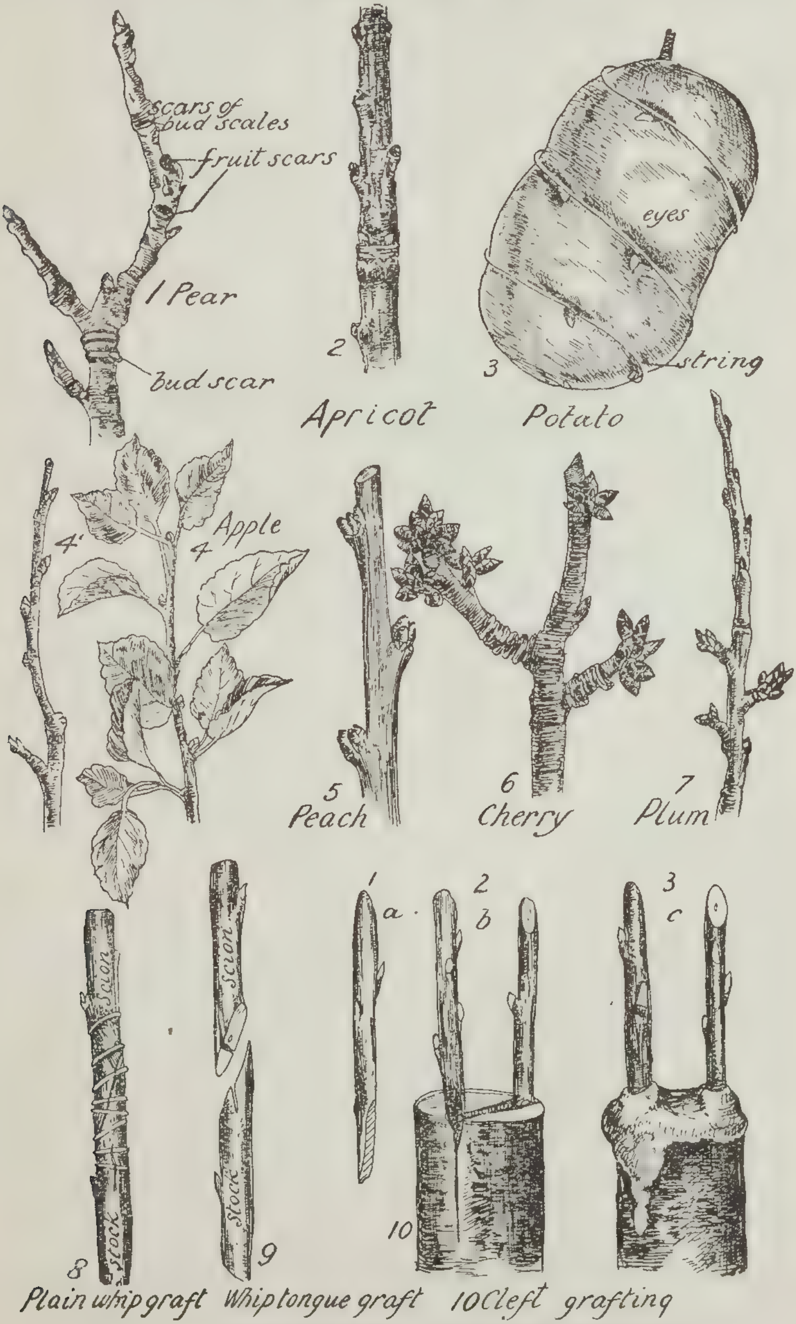

PLATE 31.—SOME TWIG AND BUD STUDIES.

tions return. Asparagus (30: 9; 50: 5), a vegetable, is a developing bud shoot. Cloves (30: 6) are flower buds.

Examine a bud on an apple or pear tree. When it has expanded, the scale leaves drop off. See the ring of scars (31: 1) where they were attached. The position of a former bud is denoted by this ring of scars. Speaking generally, buds form and expand once a year. In a wet summer, apple trees flower, and perhaps fruit, the second time, but that is unusual. An examination of bud scars on a branch shows usually the portions of that branch formed during successive years. From the character of the growth for that year, vigorous or stunted, the nature of the season might be inferred. This will provide many interesting exercises with twigs. Bailey, in his valuable *Lessons with Plants,* traces the varied history of a seven-year-old apple shoot, and shows that, though it tried hard by producing fifteen flowering shoots, it bore no good apples for the seven years.

Leaf arrangement has already been mentioned. Since, in general, each leaf subtends a bud, it follows that the same arrangement holds for buds. As buds are smaller, it is sometimes easier to understand this arrangement when one is working with buds, than when one is working with leaves. Wind a piece of string (31: 3) round a twig, passing from each bud to the next. It is soon noticed that buds are either opposite or alternate. If opposite, there may be two or more on the one level. If alternate, perhaps it may be found that, on reaching the third bud, one complete turn has been made, and two buds have been passed. This has been called the ½ arrangement. If three buds be placed in one turn round the stem, the arrangement is called ⅓. Next, and very common in bud arrangements, are two complete turns, bringing one back to the sixth bud vertically over the starting bud; five buds are passed in two turns, a ⅖ arrangement.

These mathematical arrangements of leaves or buds are called "*phyllotaxis*." As pointed out under leaves, the shape of the leaf can be roughly inferred from the phyllotaxis, and conversely the phyllotaxis may be roughly inferred from the shape of the leaf. The potato, a stem food store, shows the same arrangement of buds (31: 3).

When gardeners are budding trees, a thin strip of the branch is taken with the desired bud. This is inserted in

an incision of the stem on which it is desired that the new variety should grow. Thus a bud, producing branches, and, in turn, many other buds, suggests an egg. It provides a ready method of rapidly increasing one's stock, say of a valuable variety of apple or other fruit.

Grafting (31 : 8-10) is another method of increasing the supply of desirable kinds. Usually on a "resistant stock," a "scion" containing one or two buds is grafted. It is necessary to secure a close fitting, air-tight junction. A long slanting cut gives a good surface. Sometimes this is improved by cutting a whip-tongue to give a closer junction. The whole is made air-tight with grafting-wax or clay.

CHAPTER XI.

THE FLOWER.

The pea plant is flowering, and the question is, "Why has it a flower?" Observation shows that after most flowers there are fruits containing seeds, and that each fruit was preceded by a flower. A flower is a necessary stage on the way to a seed. Held to the light, the "baby seeds" may be counted in the tiny pod of a pea flower. See in other flowers the equivalent of the pod—the "seed-box."

In a white lily flower (33 : 5), the seed-box has a long stalk terminated by a sticky knob. Find the "sticky tip" (32 : 2^1) on the little pea pod and in other flowers. Six "threads" are around the seed-box and sticky tip of the lily. On each thread is a box containing pollen. Ten small, whitish pollen-boxes are around the young pea pod.

Some flowers (grasses and pine), have fine, dry pollen; others have sticky pollen which adheres readily to anything touching it. Before the pea plant dies, it must form good seeds, in order to ensure pea plants next year. The highest work of the plant is to produce good seeds. To enable the "baby seeds" in the pod to develop into good seeds, "pollen" must reach the "sticky tip," and the living part of the pollen grain must grow down to the baby seed; the seed then 'sets"; if "pollen" fails, the "baby seeds" die.

Darwin and other workers showed that, to get the best seeds, many plants require pollen from another plant of the

same kind. Seeds produced by self-pollination are less sure of germination, and usually do not produce such strong plants as seeds formed by cross-pollination.

Many plants have "pollen" and "seed-box" structures in the same flower. Some, *e.g.,* maize (34:7) and pumpkin (64:3) have the pollen structures in one flower, and the seed-box in another flower on the same plant. In others, *e.g.,* willow and poplar (59:1, 2), the pollen flowers are on one plant, and the seed-box flowers on another plant. Many plants, *e.g.,* hollyhock (38:4) scarlet geranium (38:10) and garden nasturtium (38:9), having "pollen" and "seed-box" structures in the same flower, produce the pollen before the baby seeds are ready; some, *e.g.,* ribwort, *Plantago* (40:3; 66:6) have the "seed-box" ripe before the pollen. This ensures that pollen from another flower shall be used to "set" the seeds, for self-pollination is impossible.

How is pollen brought from another flower? To discover this for common flowers provides interesting study.

Two methods are common:—

1. Wind blows pollen from one plant to another. This method is usual where plants are crowded, *e.g.,* grasses (34:1-10), and forest trees. It is wasteful, for, to ensure that each seed-box receives a proper supply, much pollen is produced. It falls everywhere until, at last, some reaches the proper spot. Should rain fall while pine pollen is being scattered, there may be a shower of "sulphur rain." Many trees and plants "smoke" as the dry pollen is liberated.

2. An animal visiting a flower might accidentally get pollen on it and leave some in the next flower visited. Insects, especially hive-bees, are pollen carriers. How are insects enticed to visit the flower? Should insects fail, seeds will not "set." Flowers with honey[1] are more likely to be visited than those without. Flowers, therefore, tend to produce much honey. A sweet scent also attracts insects. The number of flowers may be great, and the insects visiting them may, perhaps, be few. A flower more brightly colored or more highly scented than the rest will be more surely visited. The brighter and sweeter flowers are favored in the struggle for insects. Hence, flowers tend to be bright. A close connexion has been proved between insects and flowers; but for

[1] Strictly the nectar becomes honey after treatment by bees.

flower-visiting animals, there would probably be no bright flowers on the earth. Leaves may be borne below spines, but flowers, usually up above leaves, or thorns, are freely open to insects. Scarlet geranium flowers are well up.

PLATE 32.—SOME PEA FLOWERS.
St, Sticky Tip; a, Pollen Box.

Nothing should hinder the desired insects. The pea flower, as we have seen already, has in the center the seed-box with stalk, and sticky tip. Around the seed-box are the ten pollen-boxes (32: 2^{i}) on "threads." Nine "threads" have grown together, forming a tube; the tenth, the uppermost, being free, allows the bee to get her tongue to the honey produced between the inner end of the seed-box and the tube made of the nine threads. The flower must advertise the fact that it has pollen and honey for a visitor to take. To do this, some of the flower structures are modified into brightly-colored show leaves (petals). In the pea flower, enclosing the essential parts—the seed-box and pollen structures—there is a crown (corolla) of five petals (32: 2^{iii}).

The large upper show leaf in pea flowers is the "standard" or flag. The two side show leaves are the "wings," and a pair of leaves enclosing the seed-box and pollen-boxes suggest a boat-like "keel."

The bee stands on the "wings" and "keel" (32: 1). These being pressed down, allow, in gorse (32: 7) and broom, the sticky tip to spring and hit the bee on the under side of the body, covering it with pollen. At the next flower, the sticky tip again strikes the bee below, leaves some pollen and takes away some of the first pollen. The flower is now said to be cross-pollinated. In some pea-flowers (gorse and broom) the pollen is exploded (32: 1, 7) upwards once; in others, *e.g.*, sweet pea, the sticky tip works like a piston (32: 2^{iv}) and touches the bee below, leaving and taking pollen. It may do this on several occasions.

A greenish sheath around the lower part supports the "crown" and the essential parts of the flower. This is the "cup" (*calyx*). It has five small teeth or lobes (32: 2). In many flowers, the "cup" has separate leaves. The "cup" of the pea flower possibly represents five leaves fused.

Thus the pea flower consists of four sets of parts:—(1) The "seed-box structure" — "seed-box," "stalk," and "sticky tip"; (2) the ten "pollen-boxes" on threads; (3) the "crown" of five "petals"; and (4) the "cup."

In some plants, *e.g.*, eucalypts (60: 1), wattle (60: 3) (*Acacia*), and bottle-brush (*Callistemon*), there are no

bright show-leaves, but the "threads" and "pollen-boxes," being numerous and bright, are efficient advertising structures. In others, *e.g.*, the *Fuchsia* (37: 13), the bright "cup" assists in "advertising." Any part of the floral organs may be conspicuous.

The "crown," when the flower has been visited by a bee, fades, and some say the flower dies. Not so. If the flower has been pollinated, fruit and seeds develop. See the "cherry snow" and "apple snow," where the "petals," having served their purpose, fall to the ground. See the developing fruits (62: 8) in the old flowers.

Small flowers might be overlooked by busy insects, especially if plants are abundant and insects are scarce. Some plants have many small flowers close together; these make a collective show and ensure recognition by insects. each small flower is complete, and the bee visits one after the other. Clover flowers (32: 5) are interesting. The "white head" or "pink head" contains many small "pea flowers." In the white clover, there is not room for all to open simultaneously, but the plant has a successful plan of overcoming the difficulty. Find a clover head with the florets round the edge open. Find another with some of the florets turned down parallel to the stem. They are not dead, but are developing pod and seeds. When a clover flower is pollinated, it turns down. This benefits the plant by leaving room for the flower above it to open; it also benefits the bee, by saving a visit to a flower that has nothing further to give. Find clover flower-heads with one little flower waiting, and another with two waiting; find flower-heads with a few flowers turned down, many, and all turned down.

Everything possible is done to assist the insect. A "landing platform" is provided in pansy (36: 10), pea (32: 1) and scarlet geranium (38: 10), and "guide lines" direct it to the honey store. It is noteworthy that all lines on flowers direct to the honey. Can you find one that does not?

The red-flowered clover produced no seeds in New Zealand until the long-tongued bumble bee was introduced to pollinate the flowers; little seed is produced here now.

Many animals carry pollen; hive-bees are the best known. Moths flying during the evening are common; the evening

primrose (37:16) and many other flowers probably open for these moths. "Hawk moths" have a long proboscis (112:2), often longer than the insect; this is unrolled and thrust down the flower while the moth hovers over it. Even the snail crawling from plant to plant probably carries pollen. Amongst birds, honey-eaters and many parrots are of service, especially to eucalypts. The mistletoe-bird, the Australian flower-pecker, assists the mistletoe.

Ants are little used by plants in connexion with pollination, the smooth body affording little hold for pollen grains. Ants are rather robbers here, and some plants have wonderful plans and structures which keep ants from getting to their precious pollen. One such plant is the common teasel (68:8) grown at woollen-mills to work up the nap on cloth. In this plant, the bases of the paired leaves form a vessel holding about a cup of water. The stem arises from this. Ants do not cross the water to get to the flowers. Who will say that our plan of standing cupboard legs in a vessel of water to keep ants out is original?

The important part played by flower-visiting animals in beautifying the earth now becomes evident. Insect-pollination is more economical than wind-pollination, for, though the bee takes pollen for its own use, yet, if it leaves even one per cent. of the pollen grains on other flowers, it has saved the plant the expenditure of energy and material required to produce the enormous quantities of pollen necessary for wind-pollination.

Flowers therefore can be roughly divided into two groups — (1) Wind-pollinated — the pollen-boxes are exposed on thin threads easily shaken by wind (34:5), and the sticky tips are hairy, to catch the light, dry pollen (56:4). 2. Insect-pollinated—the pollen-boxes are more or less enclosed. Often there is a proper direction from which to enter the flower, as in the snapdragon and violet.

Plants are usually divided into Flowerless Plants (*Cryptogams*) and Flowering Plants (*Phanerogams*).

Those simple plants, the algae (seaweeds, some pond weeds, and others), fungi, and lichens have mostly inconspicuous reproducing parts. They are usually spoken of as cryptogams (*cryptos*, hidden; and *gamos*, marriage). They are usually not divided into stem root and leaves.

Mosses and ferns likewise are cryptogams; but mosses have leaf and stem, while ferns and club mosses have sap tubes and are hence called vascular cryptogams.

Plants higher than these have flowers that are easily seen; they are hence called phanerogams (*phaneros,* visible; *gamos,* marriage). The lower plants up to and including ferns may be said to be water-fertilized, the equivalent of the content of the pollen grain swimming in water to reach the equivalent of the "baby seed." The phanerogams are air-pollinated, the pollen being transported through air to the sticky tip. The essential parts of the flower are easily seen.

Flowering plants are divided into two classes.—I. Gymnosperms (*gymnos,* naked; *sperma,* seed). Pines and other cone-bearers (*Coniferae*) have naked seeds. Class II., Angiosperms (*angios,* flask) have the seeds in a flask-shaped seed-box and enclosed more or less by floral parts.

Gymnosperms are woody plants with usually needle-like leaves and with the pollen structures in different flowers from the seed-box. Pine (55 : 1), cypress (55 : 2) and cedar (55 : 3) are treated later.

In Angiosperms, each pollen-bearing structure (stamen) usually consists of a thread (filament) and pollen-box (anther). The seed-box (*ovary*) contains the baby seeds (ovules) and the sticky pollen-catching part (*stigma*) is often on a long stalk or column (*style*).

The leaves are parallel veined or net veined. This large group is divided into two sub-classes.—I. Monocotyledons with developing seed having one seed-leaf (cotyledon). The parts of the flowers are usually arranged in three or multiples of three. The seeds have much food for the embryo. The leaves have usually parallel veins. II. Dicotyledons, with developing seeds having two seed-leaves. The "perianth" is usually divided into cup and crown. It may be small and inconspicuous in wind-pollinated flowers, large and showy in insect-pollinated flowers.

In the large group of lily-like plants the bright part of the flower (perianth) consists of three outer and three inner bright, showy leaves. The pollen boxes are six, and the seed box is usually composed of three divisions. Usually these plants have an underground stem or bulb.

The lily family contains several well-known flowers. The lily of the valley (33: 1) bears a series of small, white, bell-like flowers, having a sweet perfume. It spreads also with

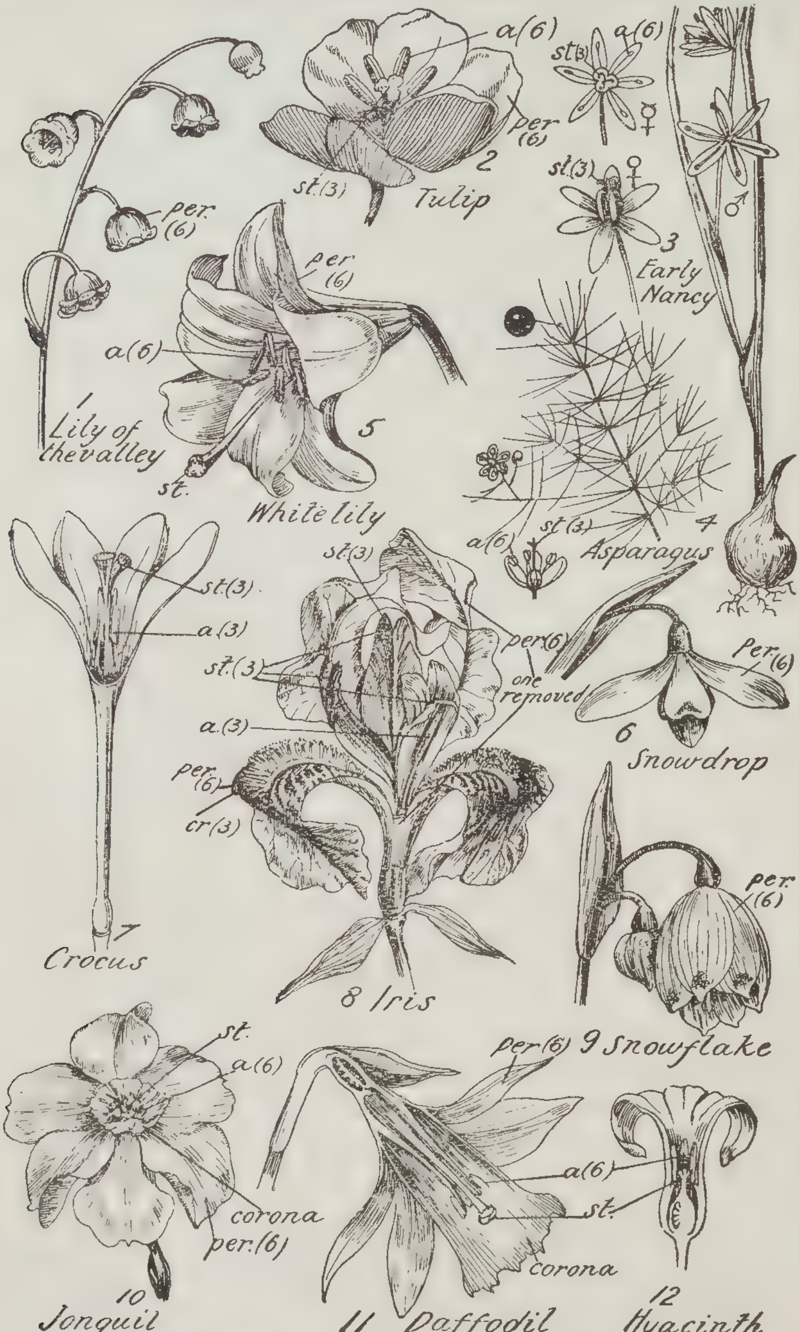

PLATE 33.—SOME MEMBERS OF THE LILY, AMARYLLIS AND IRIS FAMILIES.

Per., Perianth; ♂ Mars Arrow, Sign for Male; ♀ Venus's Girdle, Sign for Female; ☿ Sign for Male and Female Together.

the aid of a creeping underground stem. The tulip (33: 2) bears one large flower on a long stalk. The six bright flower leaves are separate. The loosely bound bulb is a store of food in the base of the leaves. The plant thus gets an early start in the spring.

Early Nancy (33: 3), the little lily often called the "Harbinger of Spring," is interesting, chiefly on account of its great variation and its early flowering. The number of leaves varies; the height of the plant varies greatly; the pollen boxes vary from 1 to 11; the flower leaves vary from 1 to 10; the lobes of the seed-box vary from 1 to 6; the sticky tips vary from 1 to 6; the color of the flower leaves varies from plain white to white with a purple bar. Most of the flowers contain both pollen-boxes and seed-box; some, however, have seed-box only and some pollen-boxes only; possibly the plant is still undergoing evolution. Asparagus (33: 4), though often called a fern, is a lily. The small creamy flowers have six pollen boxes and a seed-box with a three-branched sticky tip. The fruit is a berry on a rigid stalk. The apparent leaves are "cladodes."

The white lily (33: 5) is called in Victoria the Christmas lily. The bulb (50: 13) is made up of loose leaves, the bases of which are packed with food. The hyacinth (50: 12; 33: 12) also is a lily, the flowers being borne in a pretty cluster. The onion (50: 11) and garlic are two of the lily family used as vegetables. In the flower of all lilies, the seed-box is above the base of the flower leaves. The butcher's broom (18: 1) is also a lily. It is a well-known "leafless" plant. The Australian grass tree or "black-boy" is also a lily. The gum from this plant is rich in picric acid, which is used in a high explosive (lyddite).

Flowers of the Amaryllis family (33: 6, 9, 10, 11) have the flower leaves joined on to the top of the seed-box. These include the jonquil and the daffodil, favorites of the early spring. Most have bulbs and resemble lilies in all respects except the position of the seed-box in the flower. Jonquil (33: 10) and daffodil (33: 11) have a corona on the perianth, while snowdrop (33: 6) and snowflake (33: 9) have no corona. The snowdrop has one flower only on a stalk, whereas the snowflake may bear more.

Members of the Iris family (33: 7. 8) have three pollen-boxes and three sticky tips. Most have an underground stem. Iris, Crocus and Gladiolus (50: 7, 7¹) are common

PLATE 34.—GRASSES. NATURAL ORDER, GRAMINEAE. Pollen-Boxes (3) Hang Out Freely on Fine Threads; (9) Sticky Tips (2) are Hairy.

An Australian Blue Wren.

garden forms. The Iris (33:8; 50:10) is rather a complicated flower. The three sticky-tips are seen across three petal-like styles, each of which covers a pollen box, effectually protecting it from rain. The Crocus (33:7) is a large tubular flower. The food store is a corm.

The next big family of plants with one seed-leaf and parallel veined leaves is that of the grasses, Gramineae.

Wheat (34:4) is also treated separately on plate 56, and many of the common lawn and fodder grasses are illustrated on plate 57. The flowers of oats (34:1), with the pollen boxes freely exposed on long fine threads, are typical wind-pollinated flowers, as all grass flowers are. Barley (34:2) and rye (34:3) are other cereals. Barley grass (34:6), though common enough, is not a favorite in pastures. Perennial rye grass (34:5) and canary grass (34:8) are good pasture grasses. Maize (34:7. 7^{i}, 7^{ii}) is different from all the other grasses treated. The male flowers are borne high on the plant, while the female flowers, lower on the same plant, form a cob with a long silky tassel of sticky tips, one on each fruit or grain of maize. Quaking grasses (34:9, 10) are often picked by children for decorative purposes; each scale protects a flower with three pollen boxes and two sticky tips; the scales assist seed dispersal.

The sedge (35:4) is wind-pollinated, with the pollen boxes and seed-box usually in different flowers; the three pollen boxes are freely exposed, hanging on fine separate threads. Sedges make up a separate family.

Water plants constitute a family. Pond weed (*Potamogeton*) of many species, and *Vallisneria* are often to be met with in lagoons. *Zostera,* the common "sea-grass" used for stuffing cushions and for packing, is not a true seaweed.

The pond-weed (35:10) has a perianth of four leaves, four pollen boxes, and four sticky tips. Vallisneria (35:6; 188:1) is one of the wonders of the plant world. The pollen boxes and seed-box are on different plants. The seed-box flowers (suggesting a piece of stout fencing wire) are on long fine spirals, which uncoil to place the flower at the surface. The flower has three small lobes. The male flowers form in a semi-transparent sheath on a different plant; each is a minute spherical ball. These rise to the surface, divide into three, erecting the two pollen boxes.

The minute white flowers are drifted about until they meet the small sticky tip, when pollination takes place. The spring coils, and the flower goes below to perfect the seeds.

The Arums are a big group. The common white arum, *Calla* (35 : 2) is wrongly called a lily. The white advertising structure corresponds to the brown bud-cover—the

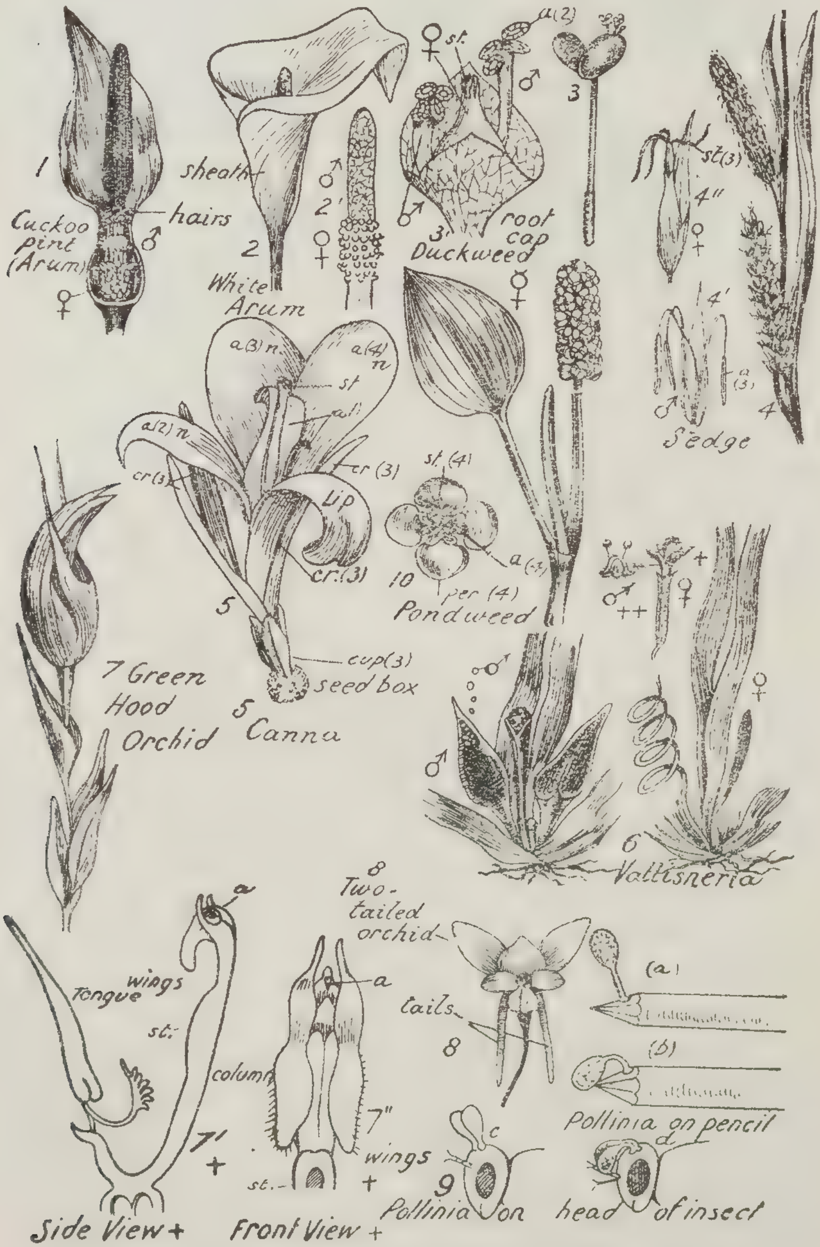

Plate 35.—FLOWERS, ARUM TO ORCHID.
3', Greatly Enlarged; 7^{ii}, Enlarged front View of 7^{i}.

"spathe" of the jonquil. Many male and female flowers are grouped on a central yellow axis, or spadix, though the whole is usually spoken of as one flower. The male flowers are above and the white pollen can often be rubbed off; the female flowers are below (35 : 2^1; 68 : 4). The nauseous odor of the cuckoo-pint (68 : 4), repulsive to us, is doubtless pleasant to the flies that assist pollination.

The floating duckweed *Lemna* (35 : 3, 3^1; 188 : 3), and the related *Wolffia*, are the smallest of flowering plants. It is seldom indeed that a flower is seen. It is disputed as to whether the structure is one flower (35 : 3^1) with two pollen boxes and one sticky tip, or three flowers, two male and one female flower in the one sheath.

The Canna (35 : 5) and the banana are the chief members of another order of monocotyledons. The canna is a complicated flower with one functional pollen box. The cup has three short leaves and the crown three narrow leaves. The sticky tip stands in the middle of the flower. The one functional pollen box is borne on the edge of a broad petal-like "thread." In addition, there are three sterile petal-like threads (*filaments*). A lip in front of the sticky tip and pollen box completes a complicated flower.

Orchids form a big order of plants though they all belong to the one family. Some are conspicuous, others minute; the flowers are mostly insect-pollinated and are often extremely complicated. They are found everywhere except in the coldest and driest regions.

Some grow in the soil, producing tubers—food stores (50 : 3) for next year. Some in tropical forests are epiphytes (22 : 7) growing on other plants or rocks. The roots of these are fleshy and absorb moisture from the air. The flower is seldom regular. The column bears the pollen structures and the sticky tip. Many kinds growing in Southern Australia are known to children. Some suggest mosquitoes, some spiders, and some goats, and children use such names for them. The green-hoods (35 : 7) bearing one flower on the end of the stem are favorites in early spring.

The two-tailed orchids *Diuris* (35 : 8), some plain yellow, and some spotted, hence called leopards, will illustrate the common mode of pollination.

There are three outer show-leaves and three inner, the lowermost of which usually forms a landing platform for the insect. As it tries to take honey from the spur, its head comes in contact with a column consisting of pollen and seed-box structures fused. The pollen, instead of being in dry or sticky grains, forms two waxy masses, the "pollinia." The base of the pollinia adheres readily to the insect's head. The pollinia change (35: 8c, d) and slope downwards. When entering the next flower of the same sort the pollinia touch the sticky tip, which is placed lower on the column than the pollen structures.

Children sometimes pollinate these orchids by withdrawing on a lead pencil the pollinia (35: 8a, b), and then putting the pencil into another flower.

The green-hoods are pollinated by small insects, and do not show the pollinia so well. The seeds are usually extremely small and may be blown far by the wind. Mr. Pescott, F.L.S., recently showed that few seeds germinate, and that seedling orchids are rare in Victoria. Apart from gardening considerations, and the fact that much money is spent on hot houses for the growth of tropical orchids, orchids are of little economic importance. Vanilla, a flavoring material, is the chief commercial product of orchids.

Flowering plants with seeds having two seed-leaves (*Dicotyledons*) have usually leaves with net veins, and have the floral parts arranged in fives or fours. A definite cambium or growing layer is present, and the stem grows in annual rings. The leaves may have stipules, but rarely have leaf-sheaths. The perianth can usually be separated into cup and crown. In the first group, the leaves of the crown—petals—are free; and, in the second group, they are united.

In the Buttercup family (36: 1-4) four flowers are figured. The common buttercup (36: 1) is a favorite with all children. The bright enamel of the golden petals gives a yellow reflection on the throat, and satisfies a child that his mate "likes butter." Each petal bears an interesting honey-pocket or nectary (36: 1^{i}) near its base. There are many pollen boxes and many seeds are borne, each in a flat structure (36: 1^{ii}) bearing a sticky-tip. The Clematis, or traveller's joy (36: 2), as handsome in the fruiting stage as

when flowering, is a well-known leaf-stalk climber (14: 15). The flower has no crown, but the cup is brightly colored. In the columbine (36: 3) the five cup-leaves resemble petals,

PLATE 36.—FLOWERS, BUTTERCUP TO CARNATION.
n(2), Nectaries two; a(m) Pollen-Boxes many.

and each of the five petals has a hooked honey-producing spur. The larkspur, *Delphinium* (36:4), has the nectar gathered in a spur, which is formed by both crown and cup. The five cup-leaves resemble petals.

The poppy (36: 5) is a favorite garden flower, and has a characteristic large seed-box. Poppies are herbaceous plants with a more or less poisonous milky juice from which laudanum and opium are made. The two leaves of the cup ($36: 5^{I}$) are pushed off as the flower opens. There are four large papery petals. The pollen boxes are numerous, the sticky tip consists of ridges on top of the seed-box. There is no honey, but insects visit poppies for pollen.

The wallflower (36: 6) has four cup-leaves and four petals forming a cross. The pollen boxes are six, four inner above and two outer below, with two nectaries at their bases. The fruit opening on each side of a central axis (48: 4) liberates the seeds. Many vegetables, *e.g.,* cabbage and turnip, belong to this family, the *Cruciferae;* many, *e.g.,* mustard and horse radish, contain a pungent oil.

In the carnation family (36: 11) the long tubular cup has five teeth at the mouth; it is enclosed by short bracts. It has a sweet perfume and is a favorite in the garden. Sweet William and the catchfly (68: 6) belong to this family.

Mignonette ($36: 7\text{-}7^{II}$) is a sweet-smelling garden flower. The cup bears five narrow leaves; the four petals bear many finger-like processes; there is a wide disc between; the many pollen boxes are brownish-red in color. The seed-box opens at the top to let the seeds escape.

The trigger-plant (36: 8) is one of the common wild flowers of Australian railway enclosures. Many pink flowers are borne on a long stem. The two double pollen boxes and sticky tip are borne on a long arm, which is fastened back (8^{I}). A touch at the nectary acts as a pull on the trigger of a gun.

The arm quickly comes over (8^{II}) and hits the bee's back, leaving pollen and taking some placed there by a previously-visited flower. The trigger-plant shows extremely rapid movements. The arm is said to return to its "ready" position and is again released when the sticky tip is ripe; cross-pollination is thus secured.

The pansy (36: 10) is a favorite in Nature-study, and "the man in the pansy" (36: 10[1]) is a most interesting floral structure. If the spurred petal is removed wholly without damaging the nectaries, the man is seen sitting in the pansy, his legs, the nectaries, hang freely, his body, the five pollen boxes, has on a sailor jacket with an orange collar open at the neck. The green head bears a mouth and a thick lip, the sticky-tip. The five double pollen boxes open inwards, and the pollen is held by the orange collar or flap along the summit of the pollen boxes. When touched by the bee's tongue this collar dusts it with a small quantity of pollen, and, at the next flower, some pollen is caught by the thick lip (sticky tip); pansies produce little pollen.

All essential structures must be placed with regard to the spur—the important part for the bee. Not even a needle could go into the spur without touching the sticky tip and disturbing the pollen boxes.

The nectaries are two long processes of the two front stamens. The cup takes no part in the formation of the spur. The large petal is a landing platform. All the lines on the pansy flower lead to the spur. Dense white hairs block a wrong passage that might be taken at the side of the spur. All help the bee to find the nectar, and to effect (unconsciously) cross-pollination.

The violet (36:9) is similar in structure to the pansy, except that the sticky tip is not a thickened bar on a rounded head, but is a bent structure. Early in the season violet flowers are well above the leaves; later, flowers and leaves are mixed, and, later still, small rounded self-pollinated flowers that never open are produced. These are called "cleistogamous" (hidden marriage) flowers.

The pansy and violet are suited to a bee with a longer tongue than that of the hive bee (103).

Members of the rose family (37:1-10, 12, 14) are common in orchard, garden and field; indeed, most of our edible fruits are members of this large and diverse order. "By their fruits ye shall know them," but the fruit of a burr like the bidgee-widgee (67:8) does not suggest an edible fruit like the apple (62:10, 11), peach (44:7), strawberry (44: 11), or hawthorn (44: 3).

Apples (44:1), pears (2) and quinces (4) are somewhat

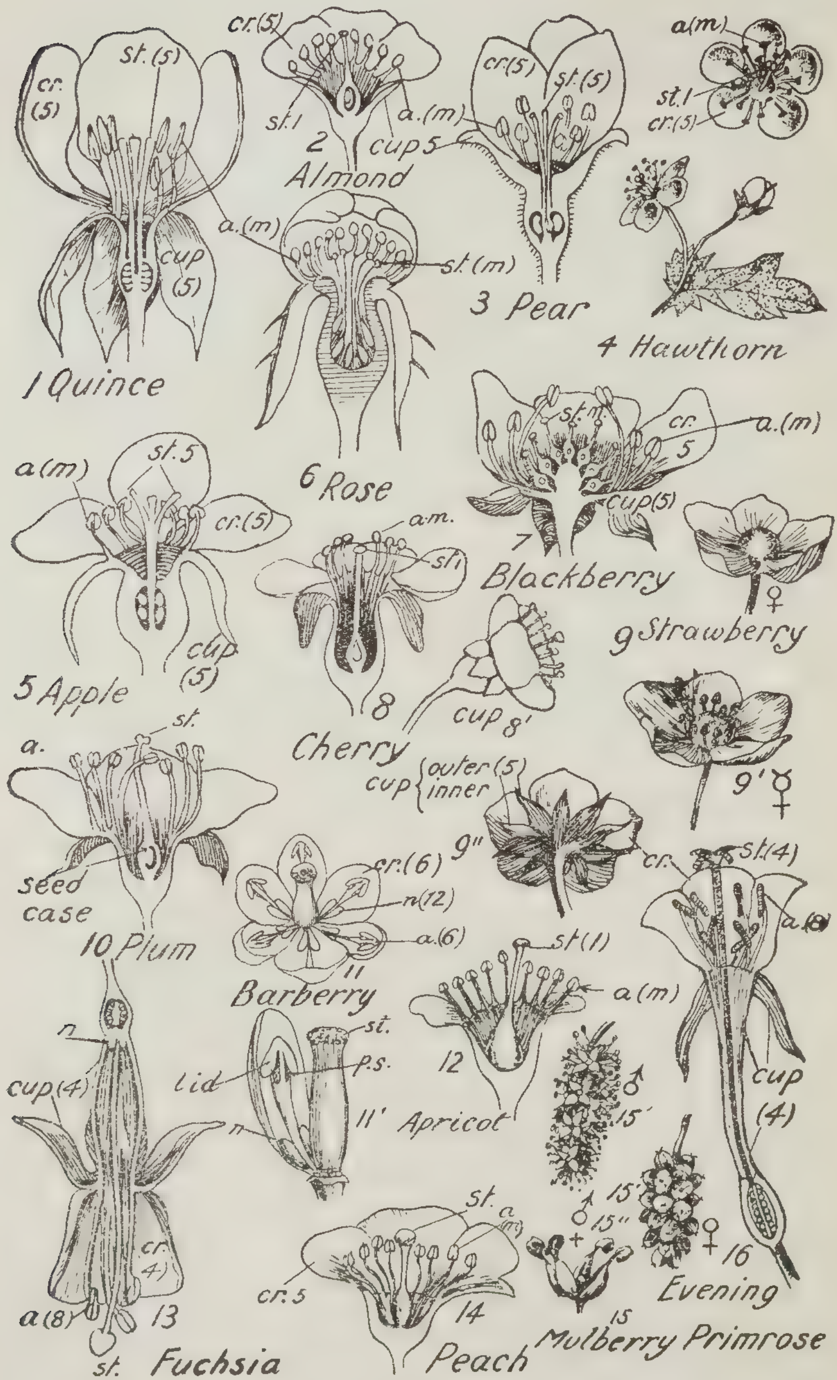

PLATE 37.—FLOWERS, QUINCE TO EVENING PRIMROSE.
For Clearness some Flowers are Shown in Section.

similar fruits, and have somewhat similar flowers. There are five sticky tips and many pollen boxes in each flower; the base grows up round the essential floral parts (62: 8); the remains of the pollen boxes can often be seen at the top. The hawthorn (37: 4) is a member of the apple section of the family, though but one sticky tip is present. Cherry (37: 8), almond (37: 2), plum (37: 10), apricot (37: 12) and peach (37: 14) are somewhat similar in structure in the flower. Blackberry (37: 7), with many one-seeded fruitlets grouped about the outside of the axis, differs from, say, the rose flowers with baby seeds arranged on the inner wall of the hollowed axis (37: 6; 45: 12). The raspberry resembles the blackberry.

The strawberry (37: 9, 9^{i}, 9^{ii}), with many small fruitlets partly in a fleshy axis (44: 11), has an inner and an outer cup. Some strawberry flowers have no pollen; these bear fruit. Others have both pollen boxes and sticky tips.

Nectar is produced on the inner wall of the hollow part of the flower. This hollow part falls from such fruits as cherry and plum, but grows up and encloses the pollen boxes in the apple-like fruits. The barberry (37: 11, 11^{i}) has six peculiar pollen boxes opening by valve-like lids. There are two honey glands at the base of each of the six petals. The fuchsia (37: 13) is a garden favorite. The cup is usually brightly colored and assists in attracting insects. There are four cup leaves, four petals, and eight pollen boxes. The mulberry flowers (37: 15, 15^{i}, 15^{ii}) have separate sexes. The male clusters bear small flowers with four pollen boxes. The female flowers have two sticky tips each. The cup and seed box (45: 10, 10^{i}) become succulent and consolidated. The evening primrose (37: 16), a garden escape, is a troublesome weed in some districts. It is an erect biennial with a stout taproot. The large, yellow, scented flowers open towards evening and on dull days.

The Passion Flower (38: 1) is complicated and interesting. The pollen threads form a column on which the seedbox with three sticky tips is supported. There are five large pollen boxes joined high up on the central column. The plant is a native of the forests of South America and the West Indies. Christian traditions were soon fitted to the flowers. The five pollen boxes were the wounds of Christ;

the three styles with sticky tips were likened to the three nails by which He was nailed to the Cross. The central column, the pillar to which He was bound, while the radiating processes all round were likened to the crown of thorns. There are five cup-leaves and five petals.

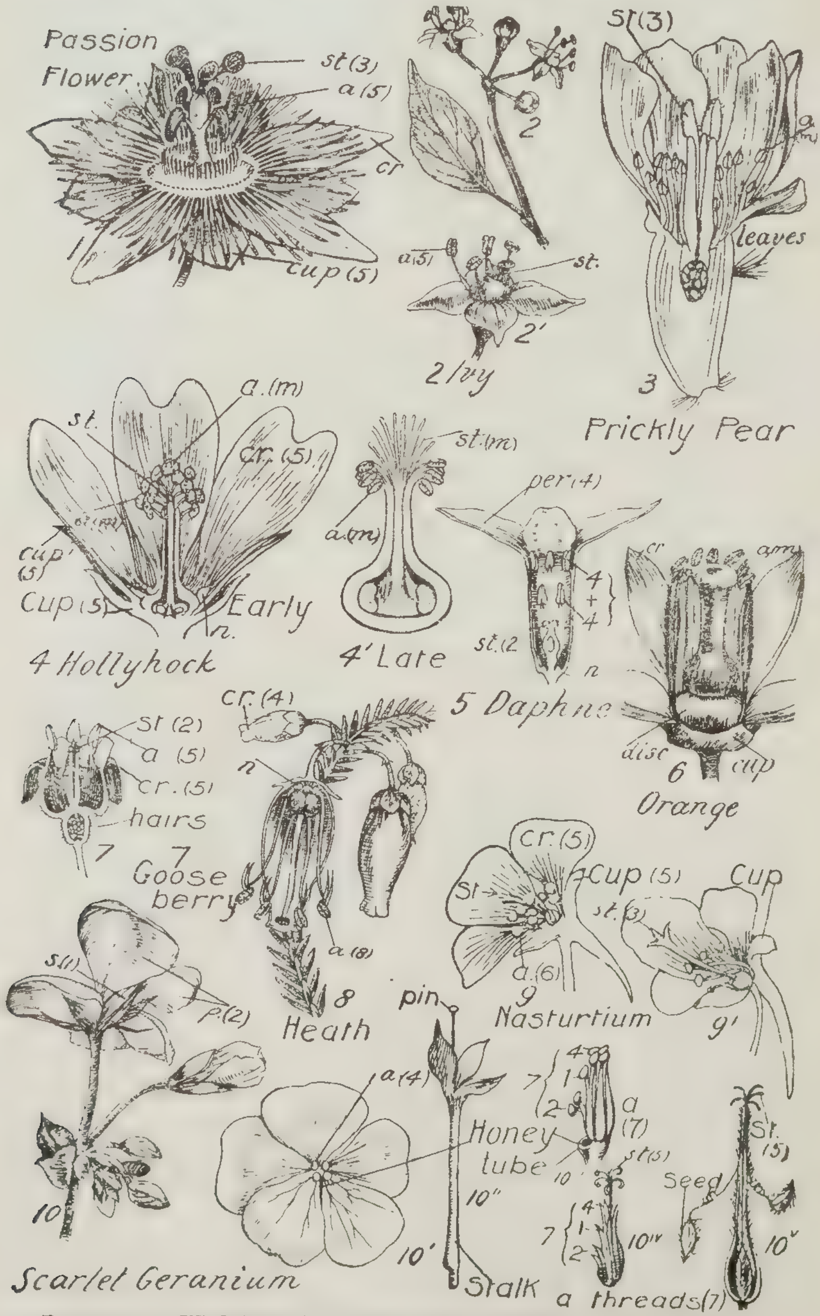

PLATE 38.—FLOWERS, PASSION FLOWER TO SCARLET GERANIUM.

Ivy provides good studies. It is a root climber (28:11); the lobed leaves form a close mosaic (11:3) on the side of the stem fastened to a wall by means of aërial roots (22:1). When mature, the reproductive shoots grow erect, with leaves resembling those of a pear-tree (38:2), the so-called "tree-ivy." Cuttings of this do not take the climbing form. The flowers (38:2) are much visited by flies. Ivy is not a parasite; it makes its own food, but saves making a big stem to support the many leaves by clinging to walls and trees; the fruits are poisonous.

The prickly pear, *Opuntia* (18:7, 38:3), has proved a very troublesome and expensive pest. A successful method of treatment is still awaited. The large fruits (45:8), somewhat resembling figs, contain many seeds. These are said to be spread by birds, including emus. The plant, a member of the cactus family, was introduced from Mexico by the early Spanish voyagers to countries about the Mediterranean, where it is often called the Barbary fig.

The hollyhock (38:4) is our representative of the mallow and Hibiscus family. The pollen threads form a column which supports many pollen boxes. Later, the sticky tips (4^1), one for each division of the seed-box, grow up through this column and are spread out. Self-pollination is improbable, the pollen being shed first. The nectar glands are in the base of the crown; there is a double cup on the hollyhock. The sweet perfumed daphne (38:5) is a favorite garden plant, though all parts of the plant are poisonous. There is no real crown; the perianth, probably a calyx, has four lobes and bears eight pollen boxes, four above and four below. The sticky tip and seed-box are low in the small bell flower; the nectaries are close alongside the seed-box.

Orange blossom (38:6), on account of its associations, is interesting. The cup is small; the crown has five petals; the many pollen boxes surround the disc which secretes nectar and bears the seed-box and the stalk, terminating in the swollen sticky tip. The leaves (15:16) are jointed to the leaf-stalk (14:20), and are sometimes regarded as compound leaves, though there is only one leaflet; these fragrant leaves are dotted with glands. The fruit is a berry (45:7) made up of several (often eleven) divisions—"liths"; each has many seeds (pips). Each slippery pip contains several

baby plants, the material not being differentiated into one embryo and food; the strongest plantlet absorbs the others in germination. The skin contains many glands which secrete a strong scented oil giving the bitter flavor. This oil is used in the manufacture of eau-de-Cologne. The sweet pulp which is eaten is really fleshy hairs. Occasionally in a dry season, one meets with an orange that is not nice to eat, the hairs being rather dry. If the skin is squeezed near a candle the oil burns.

The gooseberry flower (38:7) has five pollen boxes and two sticky tips. The brown cup remains on top of the gooseberry fruit. Erica, the garden heath (38:8), has eight pollen boxes and a sticky tip on a long stalk. In a suburban garden the spine-bill honeyeaters puncture many of the tubular flowers and extract the honey. It was noticed that hive bees visiting the flowers frequently worked through the hole in the crown and so did not help the flowers in cross-pollination. The garden nasturtium or Indian cress (38:9, 9^{i}) has a long spur formed by a cup leaf. The pollen boxes, a few at a time, project on the way to the spur. Later, the three-branched sticky tip projects before the spur. The spur is too long for the tongue of a hive bee.

The flower of the common scarlet geranium (38: 10) provides an excellent study in cross-pollination. An early flower not long opened shows the seven pollen boxes; four above, one in the middle, and two lower down on the central column (10^{iii}) above the hole to the honey tube in the flower stalk. A pin (10^{i}) can be placed some distance down this honey tube. The pollen has three chances to get on the tongue of the bee. A landing platform of two petals is supported by the large cup leaf at a higher level than the other three (10). Guide lines lead to the honey-tube. The umbels of flowers project well above the leaves. All is clear for the insect. In older flowers the pollen boxes have gone, the seven threads (10^{iv}) are left, the five-branched sticky tip (10^{iv}) is now ready. The style between sticky tip and seed-box elongates, and the five seeds (10^{v}) are perfected on the outside of it. Later, the long process twists the seed off, assists in some species (47: 17) in its dispersal, and assists later in planting the seed (4: 8; 66: 9). The "scarlet geranium" is really a *Pelargonium*, a related genus.

The primrose (39: 1) is a favorite plant in pollination studies. Not only is cross-pollination essential, but cross-pollination from a form with pollen boxes high on the crown (1a) and above the sticky tip to a form (1b) with pollen boxes lower on the crown and below the sticky tip. The cowslip is one of these interesting forms. Those with

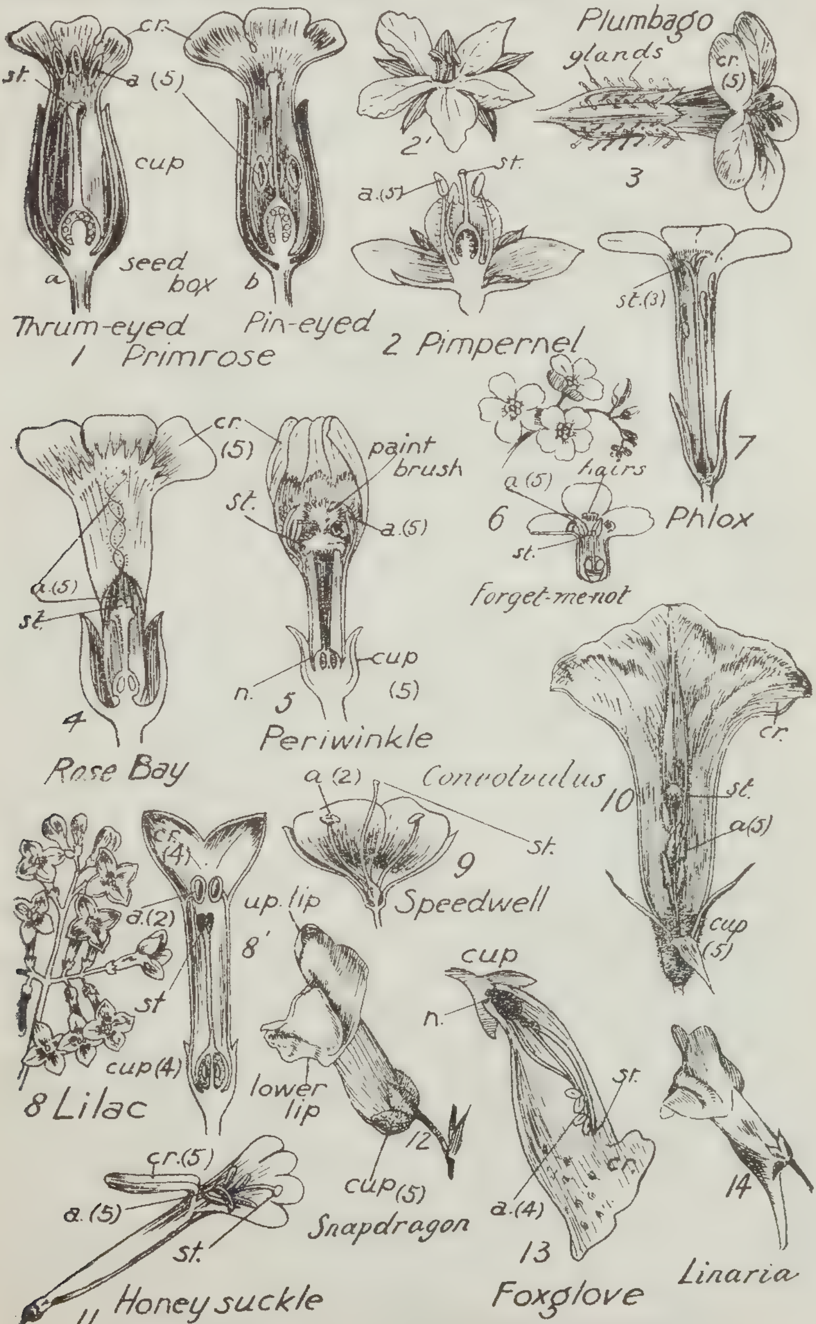

PLATE 39.—FLOWERS, PRIMROSE TO LINARIA.

high pollen boxes are "thrum-eyed" or short-styled forms (39: 1a), and those with pollen boxes lower down are "pin-eyed" or long-styled forms (39: 1b). The primrose cannot use its own pollen; cross-pollination is essential to the production of seeds. The short-styled forms put pollen on a bee's head. When she visits a long-styled flower, the sticky tip is there and some pollen in brushed off on to it. Meanwhile, the pollen boxes lower down have put pollen on the bee's tongue. At the next short-styled flower, the sticky tip low down takes some pollen, while the tongue is feeling for nectar in the bottom of the crown. The primrose has little pollen; some plants provide much.

The introduced scarlet pimpernel (39: 2, 2^1) or "poor man's weather-glass," is more fully treated later (66: 4). The small single flowers on long stalks have five pollen boxes and one sticky tip; they close on the approach of rain.

The plumbago (39: 3), with its cup covered with sticky glands that probably assist later in seed dispersal (47: 7), reminds one of the more famous *Pisonia* fruits (68: 7). The delicate blue crown has five lobes. There are five sticky tips, but only one seed in the seed-box. Possibly the sticky glands keep unwelcome visitors (ants) from the flowers.

The periwinkle (39: 5) has a peculiar complicated arrangement of sticky tip and pollen boxes. The threads of the pollen-boxes arise below the sticky tip, bend outwards, and bring the five pollen boxes in a ring above the flattened top of the style. The sticky tip is a broad, smooth band round the top protected from self-pollination by a ridge above it. A long-tongued insect, a moth, butterfly, or a long-tongued bee can extract honey from the flower. The style and stigma are often called the "paint-brush."

The oleander or rose bay (39:4), an evergreen shrub from the Mediterranean, stands drought well. It flowers in midsummer. The five pollen boxes have most peculiar long hairy terminations that prevent any but a long-tongued moth or butterfly from reaching the nectar, though a long-tongued bee by crawling partly into the flower can reach it. There is a well-developed corona inside the crown marked with guide lines. Each of the five threads bearing pollen boxes is fused with the upper part of the style, so that the long-tongued insect has only five gaps through

which to thrust the tongue in search of honey. This, with the long processes of the pollen boxes, provides an effective apparatus for cross-pollination by special insects.

The convolvulus (39: 10) has the pollen boxes at different heights grouped into a column round the style. Each sheds pollen on the outer edge. An insect crawling into the flower gets dusted below. The only entrance to the honey is through the slits between the pollen boxes. The flowers, closing when cloudy and at night, are evidently pollinated by day-flying insects.

The flower arrangement of the forget-me-not (39: 6) has been compared to the curve of the tail of a scorpion or of a snail-shell. The sky-blue flower has a yellow corona, which directs insects to the nectar and gives such a narrow entrance that water cannot enter (43: 8) and the pollen remains dry. The Phlox (39: 7), with long tubular flower, has the pollen boxes on short threads arising from the wall of the crown; the sticky tip has three branches. Lilac (39: 8) flowers form a cluster, the small flowers uniting to make an attractive mass easily seen by insects. There are two pollen boxes (8^1) in each flower. The snapdragon family contains several common plants. The snapdragon itself (39: 12) requires a heavy insect such as a bumble bee to force open the lower lip. Toad-flax, *Linaria* (39: 14) is like a small snapdragon, but has a spur on the long tubular crown. The foxglove *Digitalis* (39: 13) is poisonous; it has an open crown. The four pollen boxes are close to the sticky tip. The *Bartsia* (29: 5), parasitic on grass roots, is an introduced plant of this family, and is spreading widely through pasture lands; it causes a purple patch in mid-spring. The Veronica or speedwell (39: 9) has only two pollen boxes in each flower. The honeysuckle flower (39: 11) favored by twilight-flying (crepuscular) insects which hover, has no landing platform. On the other hand, the flower parts are turned back out of the way of the rapidly moving wings. Long-tongued hawk moths (112: 2) extract nectar readily from the long tubular crown. The white flowers are easily seen in the dusk. A sweet perfume also helps the insect. Older flowers are yellow; when pollination is effected, apparently the flowers change color, as do some others, *e.g.*, Lantana.

Sage and Salvia (40: 1, 1^{i}, 1^{ii}) have interesting cross-pollinations. The two pollen boxes are on long levers (1^{ii}). The bee pushes her head against the lower end of the lever (2a) and the pollen boxes gently touch her on the back. Later, the sticky tip (1^{i}) is ripe and projects from the hood of the flower, touching the bee on the back and taking some pollen. Self-pollination is impossible. The long tubular flowers of the bonfire salvia (40: 2a, b) have

PLATE 40.—SOME FLOWER STUDIES.
The crown is partly or wholly removed in 1^{ii}, 2, 4^{1} and 7.

a similar action. The ribwort (40: 3a-c) is a common plant that has the sticky tip ripe before the pollen boxes. Many flowers are grouped on a long stalk. Self-pollination is impossible in this wind-pollinated plant (66: 6). The blue bell (40: 4) is interesting. Cross-pollination is the rule. The pollen boxes, long and narrow, are ripe first. They are soon lost, then the three-branched sticky tip is ready for cross-pollination. The Australian blue bell varies much in size. Its flowers are open on sunny days the whole year through. The flowers close as soon as the weather becomes cloudy, and in the afternoon. A small black wasp seems to be partners with the plant. It is said to be several degrees warmer in the flower at night, and the wasp is often shut in when the flower closes.

Hogweed (40: 5, 5^1), wireweed, or knotweed, with its ensheathing leaf-stalks, its long prostrate stems and small flowers, is a plant of the dry weather. When other annuals are dying off, the hogweed develops and has some grazing value; it is a troublesome pest in cultivated ground. Docks (40: 9) are troublesome weeds in damp places. The long tap-root renders eradication difficult; the floral parts are arranged in threes. The Acanthus (40: 6), famous in Grecian art, has a crown of one petal. The pollen boxes are pressed together. A large, strong insect forcing its way in separates them and liberates the pollen. Kerner refers to this as the "sugar-tongs" variety of pollen liberation.

The pumpkin (40: 7), melon, and gourd family have the pollen boxes and seed-boxes in different flowers on the one plant. Female flowers can be recognized at once by the large seed-box; the pollen boxes are grouped in a column. People sometimes say the seeds are not setting in the pumpkin flowers, and blame the cold weather, but, of course, no seeds can set in the pollen flowers. The common pincushion (40: 8) has a head of small flowers. Pollen boxes and seed-box are in each floret; the pollen boxes being ripe before the sticky tip, self-pollination is improbable.

The so-called water-lilies (40: 10), common in lily ponds at botanic gardens, are not lilies. They belong to the family of the *Nympheas*. The common water-lily is interesting as showing the passage from pollen structure to petal (40: 10^1); the numerous petals are floral leaves specialized

for advertising. The Victoria Regia, with a giant floating leaf, and the Sacred Lily of Buddha (the lotus of the Indies and North Australia), are members of this family.

The most highly specialized and developed of flowering

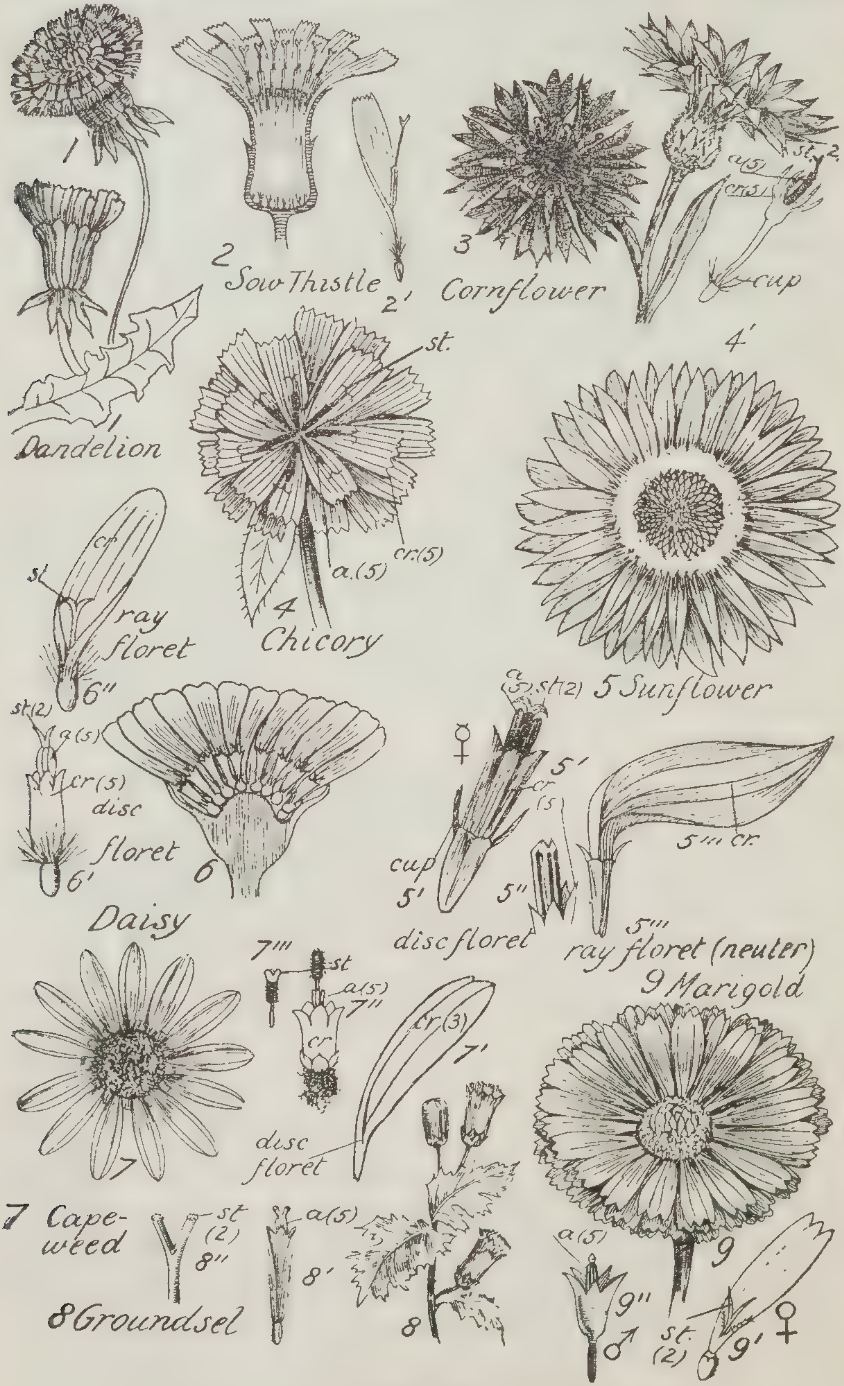

PLATE 41.—COMPOSITE FLOWERS

plants are the Compositae, the largest family of plants, and one of the most successful and widely spread. Possibly over ten per cent. of flowering plants belong to this order. The "flower" is composed of small florets united into a compact and generally showy head or capitulum. Usually the outer flowers are more conspicuous than the inner. Nectar is available even to short-tongued insects, and the small, light seeds are readily spread. All have the cup united to the top of the seed-box and usually divided into bristles and hairs forming a pappus. The crown is always united into one structure, either long and strap-like, or tubular. Some composite flower-heads are made up of all strap-like florets (dandelion), or the outer florets are strap-like and the inner tubular (sunflower), or the whole of the florets are tubular (cornflower). The five pollen-boxes form a collar round the style. The sticky tip is always two-branched. The whole head of the flower is enclosed in a series of bracts forming an involucre. These close the flower in wet weather and at night. After pollination is complete, the bracts close the "flower" until the seeds are perfected. Few water, climbing, or epiphytic, plants belong to this order. Many have a thick tap-root. The dandelion (41 : 1) is more fully treated later (65 : 1-7). The sow thistle (41 : 2), often wrongly called the milk thistle, is a common garden and wayside weed. Its flower closely resembles that of the dandelion; much milk (latex) exudes from a broken stem. The chicory (41 : 4), with large, bright-blue flower, also resembles the dandelion flower in essential structure. The cornflower (41 : 3) has all the florets tubular; those on the outside are sterile, having no essential organs. The daisy (41 : 6) has two kinds of flowers; the outer sterile, strap-like florets have no pollen boxes (6^{ii}). Each inner yellow flower (6^{i}) has all the parts of a typical complete flower. In the sunflower (41 : 5-5^{iii}), the bright ray florets are neuters, and each has a bract attached to it. Occasionally, a reduced sticky tip may be seen on a ray floret. Each disc floret (5^{i}) is a complete flower. The capeweed (41 : 7-7^{iii}; 67 : 7) is somewhat similar to the sunflower, but the sticky tip does not open widely; it is a mere slit (7^{iii}) at the top of the style. Groundsels (41 : 8) are probably mostly self-pollinated; few are wind-pollinated, and some are insect-

pollinated. The marigold (41 : 9-9[ii]) has ray florets that bear seeds; the tubular disc flowers bear pollen.

The thistles are mostly composites. The spear thistle (42: 1, 1[i]) has deeply dissected spiny leaves with leaf-stalk running down the stem (decurrent, 17: 10), and leaves rough above with sharp spines, and white and woolly beneath.

Plate 42.—SOME THISTLE PESTS.

The florets are tubular, and have five processes, the sticky tip branches little. This thistle is often wrongly called the Scotch thistle (42: 5). The pappus (46: 12), consisting of plumed hairs (46: 12), assists in seed-scattering. Many "robbers" blow about after the seeds have fallen (4: 10). The creeping or perennial thistle, *Carduus arvensis* (42: 2, 2[1]), is called incorrectly the Californian thistle and Canadian thistle. It is the worst of all introduced thistles, and has a perennial root; pollen boxes and seed-box are on different plants. Baron von Mueller says this is "the most difficult of all our thistles to subdue." Ploughing assists it by breaking up and scattering the underground stem. Shore thistle, *Carduus pycnocephalus* (42: 3), has a crowded head of purple to violet flowers. It grows as well inland as near the shore, and would be better called by its other name, slender thistle. The large milk thistle (*Carduus Marianus*), called also the spotted or Maria thistle (42: 4), has leaves that may be two feet long, with white spots and markings along the veins. The purple flowers are very large. It is a native of Europe, Asia, and Africa. Professor Ewart says it has a "slight value as a fodder; but the land would be better employed growing grass or crops of value."

The true Scotch heraldic thistle (*Onopordon acanthium*) (42: 5) is a native of Europe, Western Asia, and Northern Africa, and is very rare in Scotland. Though proclaimed under the Thistle Act, it is not common here. It is not so tall or so obstructive as other thistles.

Star thistles (42: 6) have no spines on the leaves, but make up for it by having very spiny bracts about the purplish flowers. There is no pappus on the seedlike fruits. The Malta thistle (42: 7) somewhat resembles the star thistles, but has yellow flowers; there is a pappus on the fruit. The yellow Saffron thistle, or woolly star thistle (42: 8), has spiny leaves and larger yellow flower-heads. The fruits have a dense pappus. The Bathurst burr, spiny burweed, or cockle-burr (*Xanthium spinosum*) has burred fruit covered with perfect hooks. The shiny leaves are not prickly, but numerous radiating spines are placed on the stem. It is a native of Asia, Europe, and Africa. The sexes are in different flowers on the same plant. Two female flowers grow together, and the fruit is two-seeded.

One seed germinates next season, and the other one or two years later. These burrs lessen the value of the wool clip.

The protection of pollen from rain or moisture is necessary. If the pollen grain is wetted, the contents swell and

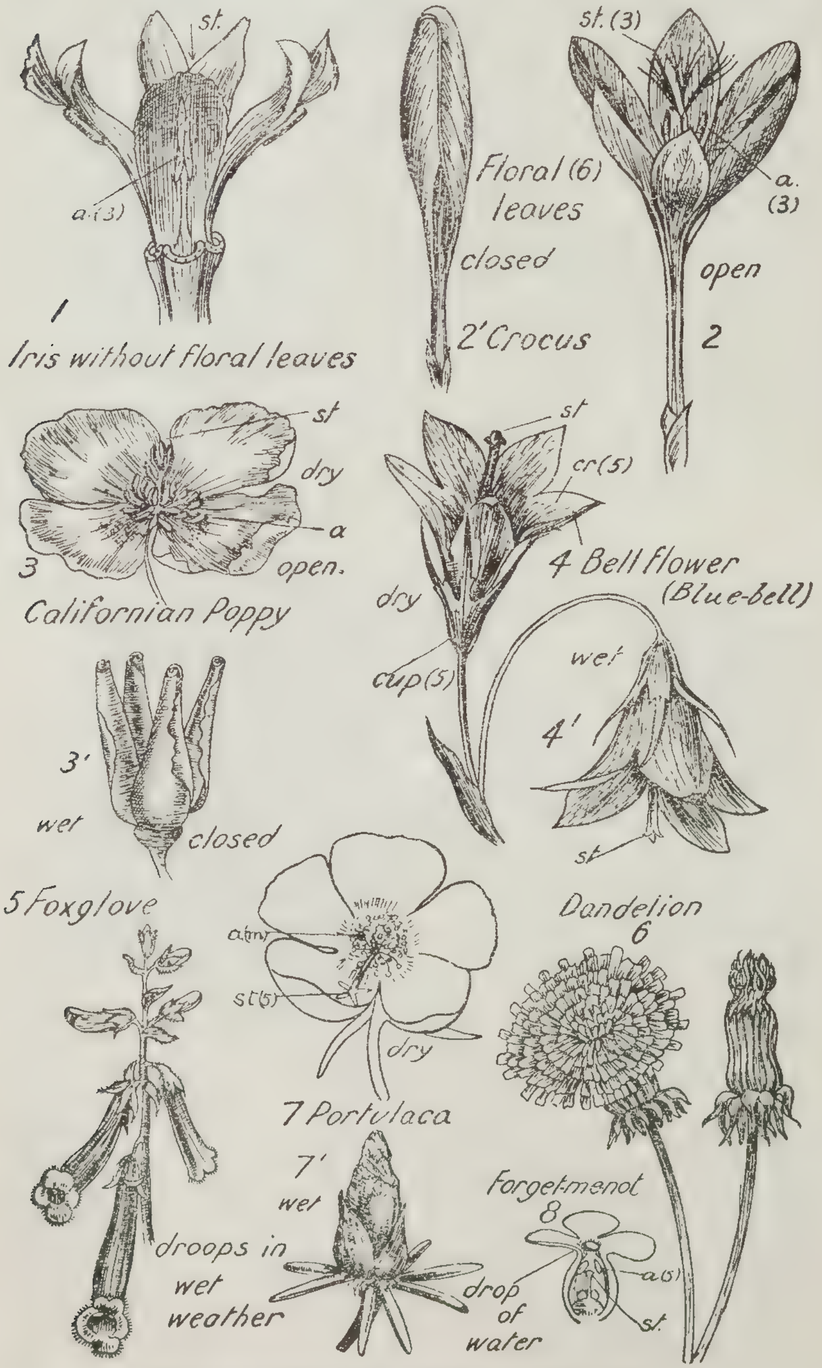

PLATE 43.—PROTECTION OF POLLEN.

burst the grain, thus destroying the pollen. Many flowers have interesting devices to prevent damage to pollen. Many close at night. The "three o'clock," *Oxalis*, is a favorite in school gardens. Some (carrot and violet) have been referred to under the "Sleep of Plants" (27 : 1, 2). Dandelions (43 : 6), Crocuses (43 : 2, 2^1) and tulip (33 : 2) close up. Others hang their heads (43 : 4^1), and any rain or moisture runs off. Some blue bells (43 : 4, 4^1) droop, some close. The Iris (43 : 1) has each of the three styles broad and petal-like; each roofs over a pollen box and effectually protects the pollen. Portulaca (43 : 7. 7^1) rolls up, as does the Californian poppy, *Eschscholtzia* (43 : 3, 3^1). Tubular foxgloves (43 : 5) droop more and the water cannot enter. The forget-me-not (43 : 8) has a narrow opening protected by hairs not wetted by the surface film. A drop remains on top and effectually prevents the entrance of water.

So sensitive are some plants that a passing cloud causes them to close. The scarlet pimpernel (66 : 4) is often called the "poor man's weather-glass." On a sunny day, there is a blaze of color from the pigface plants (13 : 11) on the street rockeries; on dull days the flowers are closed.

Even on a sunny day many plants have a definite opening and closing time. By virtue of this, Linnæus, the great botanist, constructed a "floral clock"; Kerner also prepared one. It was said that, if the spirit of Linnæus returned to his garden, he could tell by noting what flowers were open the season and month of the year, and the time of the day.

CHAPTER XII.

FRUITS AND SEED SCATTERING.

A. FRUITS.

Following the flower on the pea, the fruit containing seeds is found. Fruits follow flowers. Professor Ewart, in *The Matriculation Botany*, says, "The simplest definition of a fruit is that it consists of that part of a single flower which persists and grows after fertilization." He adds, "Fruits may either be simple or formed by a collection of free carpels, as in the aggregate fruit of the blackberry."

Some plants have fruits which are eaten, more have fruits which are not eaten. Why is it some fruits are edible and others are not? In the fruit is the seed. A plant produces many seeds. If all the seeds dropped about the parent plant and grew, they would choke one another out, or exhaust the plant food in the soil. Few would grow into

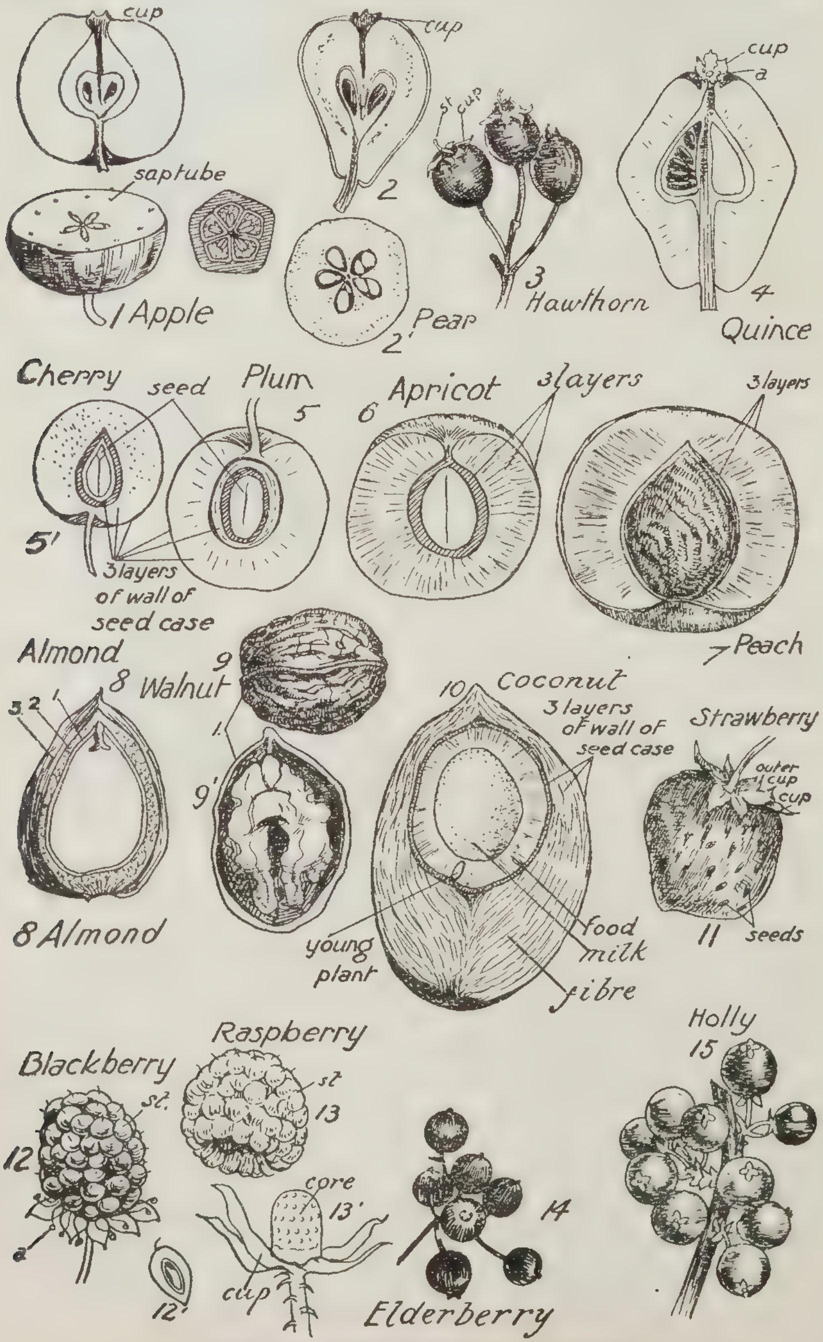

PLATE 44.—SOME FRUIT STUDIES.

strong plants, producing good seeds in their turn. To ensure future good plants, the seeds must be scattered. Different plants have different methods of scattering their seeds. Consider the fruits of cherry and blackberry. Many birds eat them, and the seeds are spread to new places. Most edible fruits, being brightly colored, are easily seen. Edible fruits are also pleasant in flavor. Animals eating some will probably return for more. Edible fruits can be regarded as payment for services rendered in scattering seeds. Until the seeds are ready to be scattered, the fruits are often protectively colored, and have an unpleasant flavor. Some fruits may even be poisonous until they are ripe. It has been established that there would be no edible fruits but for fruit-eating animals. These, taking the fruits, scatter the seeds, and do valuable work for the plant—an arrangement of mutual benefit to plant and animal. Fruits that travel in other ways are not conspicuously colored; some have an unpleasant flavor and may even be poisonous.

Fruits are of two kinds, dry and fleshy. Dry fruits, if many-seeded, open, allowing the seeds to escape. One-seeded fruits need not open to scatter the seeds; these can be scattered whole. Hence fruits are divided into those that open and those that do not open.

Fruits that do not open (indehiscent fruits)—

Apple-like fruits, or pomes, *e.g.*, pears (44: 2, 2^1), quinces (44: 4), and apples (44: 1). In the apple flower (37: 5; 62: 6) there are five sticky tips. The five divisions of the seed-box develop into the core. There may be one, two, or rarely three, seeds (62: 9, 11) in each part of the core. The hawthorn is grouped with the apple-like fruits.

Stone fruits or drupes, *e.g.*, cherry (44: 5^1) and peach (7). The wall of the seed-box consists of three parts; the inner part, the stone, is hard; the middle, fleshy and sweet; and the outside, a protective skin often brightly colored. The coconut (10) is somewhat similar, but the middle layer is fibrous instead of succulent. The middle and outer layers of walnut and almond (8) peel off. Blackberry (12, 12^1) and raspberry (13, 13^1) are aggregate fruits; each round mass suggests a stone fruit. The skin of edible fruits is an efficient protection against bacteria and other enemies. Once the skin is broken, the fleshy part is attacked, and soon

becomes unfit for food. The skin of grape and plum is often protected by a coat of wax, giving the fruit a rich "bloom." This wax protects against bacteria.

The middle and inner part of the wall of the seed-box of "berries" are fleshy, and enclose the seeds. The seed-coat

PLATE 45.—SOME EDIBLE FRUITS.
13^{111} Insect in female flower (enlarged).

of the seed itself may be pulpy, and edible. Gooseberry (19:8), orange (45:7), tomato (64:2), pumpkin (64:3), marrow, cucumber (45:4), grape (63:5), currant, date, and banana (45:2, 2^1) are berries. Man has interfered with Nature in producing the navel orange (seedless), and the edible banana (now seedless); occasionally, however, tiny seeds (45:2^1) are present; the ornamental Abyssinian bananas have large seeds and little pulp.

A pineapple (45:11) is formed by the axis of the flower cluster becoming fleshy; the separate fruits fuse together. The mulberry (37:15, 15^1; 45:10, 10^1) is an aggregate of fruits, the lobes of the calyx being fleshy and edible.

In dry one-seeded fruits the seed is scattered while in the fruit. Nuts and acorn have a hard cover; many are hidden by animals (squirrel) and forgotten; buttercup (36:1^{11}) and sunflower (2:1, 5^1) have a leathery covering. If there is no seed-cover, or if the seed-skin has grown to the fruit-cover, as in grass, wheat (3:2), or maize (3:1), the fruit is practically a seed, and the seed, a fruit. One-seeded, dry fruits may be hairy, as in the thistle (46:12), dandelion (65:6, 7; 46:9) and Clematis (46:18); they may be winged, as in the elm, sycamore, and ash.

A strawberry (44:11) has many one-seeded dry fruits placed on a fleshy axis. The flowers of a fig (45:13) are arranged on the inside of the hollow axis; each seed is really a one-seeded fruit. The pollen-bearing flowers are above, and the seed-box flowers are below. Cross-pollination is effected by a small wasp-like insect that enters at the top. The fine flavor of Smyrna figs is probably due to cross-pollination with wild figs by this small insect.

Opening or dehiscent fruits (48:1-18)—

(1) Some split open on one edge, larkspur (3), columbine (2); (2) some open on two edges (legumes), sweet pea (47:15) and gorse (47:16); (3) and some on each side of a central partition, wallflower (4), cabbage, shepherd's purse (1^1). (4) Some break into pieces, each of which opens, marsh-mallow (10); and (5) some break round the centre, scarlet pimpernel (7); and some break into one-seeded pieces, "separating fruits," maple (6), parsnip, geranium (38:10; 47:17); while some fruits open by means of pores, poppy and eucalypt (17^{11}).

B. The Scattering of Seeds.

To succeed, a plant must scatter its seeds far and wide, or at least provide for a steady extension of area.

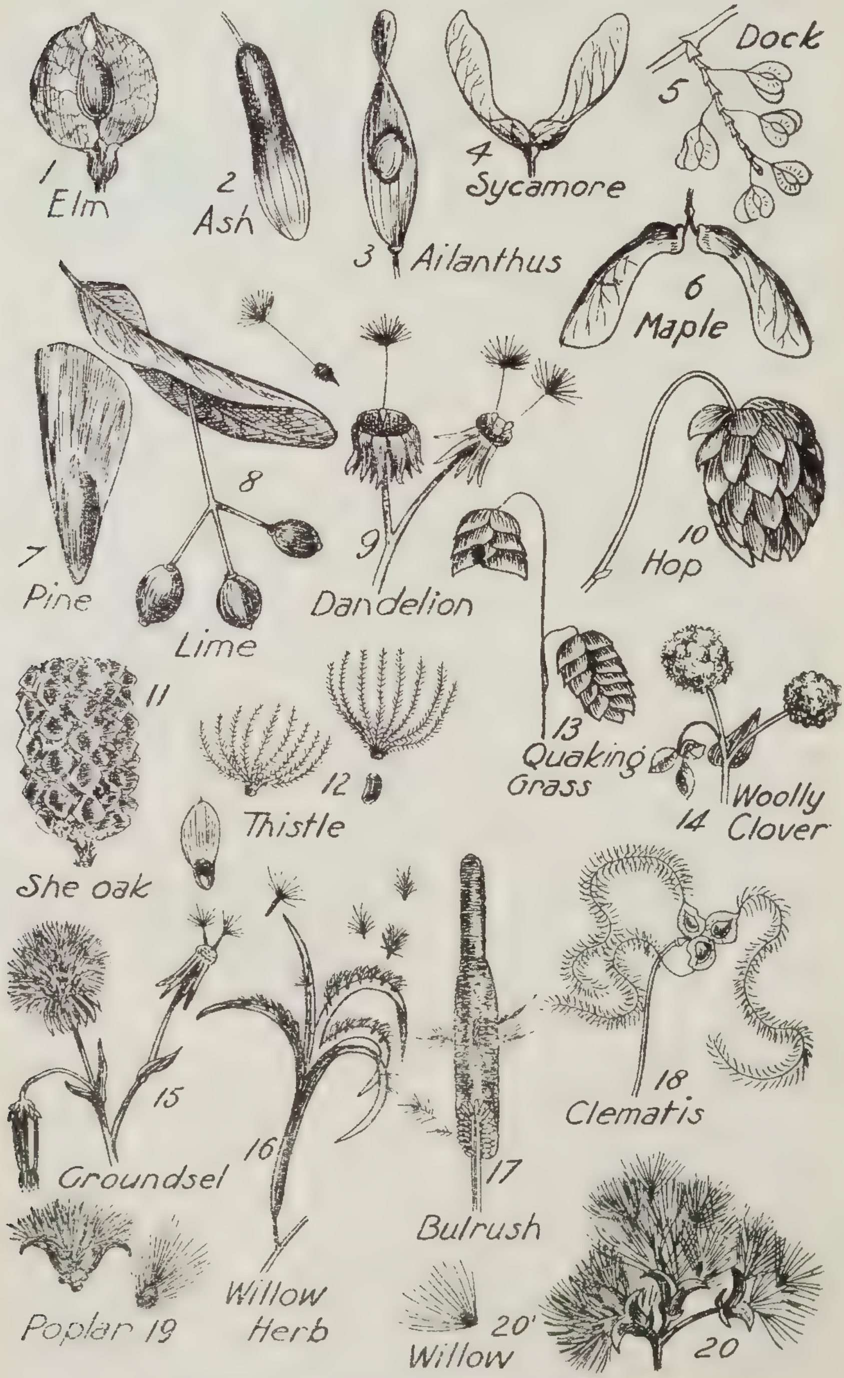

Plate 46.—SEED SCATTERING BY WIND.

First establish that seeds *are* scattered. Secondly, establish *why* seeds are scattered. Thirdly, establish *how* common plants scatter their seeds.

Collect seeds of as many plants as possible, and place them in trays of wooden matchboxes; arrange them in a neat collection, according to the method of dispersal.

There are four main methods of dispersal:—

1. Seeds scattered by the wind:—

(a) Those having hairy structures, *e.g.*, willow (46: 20), dandelion (65: 6, 7), thistle (46: 12), bulrush (46: 17), plane (58: 36), and Clematis (46: 18). The seeds soon fall from the thistle-down (4: 10); they need to reach the soil, not travel too long. (b) Those having wings, *e.g.*, pine (55: 1^5; 46: 7), ash (46: 2), sycamore (46: 4), elm (58: 2), maple (46: 6), Hakea (48: 9, 9^1), and sheoak (46: 11). (c) Those that become bulky and light, *e.g.*, capeweed (67: 7). (d) Those that have small seeds, *e.g.*, orchids. The seed-boxes open, the seeds fall out and are blown away. The seeds of some orchids are so small that it is said that over 250,000,000 are required to weigh one pound. The Island of Krakatoa, the scene of the terrific volcanic explosion in 1882, when all vegetation was destroyed, has since been colonized by plants having tiny wind-borne seeds. (e) Those that rock about, and drop seeds out of the top, *e.g.*, carnations (48: 16), larkspur (48: 3); or out of pores, *e.g.*, poppy. (f) Those that have flattened seeds, *e.g.*, wallflower. (g) Those that are borne on parts of plants that separate from the rest. These blow for miles, *e.g.*, grasses, spinifex on beach, and roly-polies on the inland plains of Australia and America. The seed-bearing parts of certain native grasses break off and blow long distances. These collect against wire-netting fences, and may form an inclined plane to the top of the fence. The succeeding seed-heads roll over the fence and continue their journey.

2. Seeds scattered by animals:—

Hooked to catch on fur or clothing, *e.g.*, Bathurst burr (42: 9), bidgee-widgee (67: 8), "grass-seeds," trefoil (32: 6). Occasionally, these hooked seeds and fruits, by working through the flesh into the animal, have caused its death. These hooks are often highly perfect. They serve

to hook on to an animal, and also, later, to catch in other objects and dislodge the seed so that it reaches the soil.

Edible fruits eaten by animals, the seeds themselves being protected from chewing and digestion; seeds protected by

PLATE 47. -SEED SCATTERING BY ANIMALS AND EXPLOSION.

hard stone, *e.g.*, plum (44: 5); seeds protected by a core, *e.g.*, apple (44: 1); seeds very hard, not easily damaged by teeth, *e.g.*, grape (63: 5); slippery seeds escape from between the teeth, *e.g.*, orange (45: 7); seeds small and numerous; if a few are destroyed, there are many more, *e.g.*, gooseberry and tomato; seeds indigestible—date (3: 4) and mistletoe (29: 4) some birds digest and destroy seeds, others do not injure them; seeds sticky, *e.g.*, Pittosporum (61: 1^{vi}) common in gardens—dry fruit opens and birds eat the sticky seeds; some are wiped off the bill. Mistletoe (29: 4) is often spread thus.

Seeds scattered by wandering animals standing on them and squeezing out the liquid mass with the seeds, *e.g.*, small gooseberry-melons in Australia, and squirting cucumber (47: 12). Darwin found 537 seeds in 6¾ ounces of mud taken from a bird (47: 5). Wallace mentions that the mud from the foot of a partridge gave 82 plants. The elastic fruit stalks of onion grass (67: 6) if displaced by wandering animals, bending back quickly, throw the seeds out. Seeds are liberated from the crops of birds killed by birds of prey, and in other ways. Pellets ejected by owls contain seeds from birds eaten. Seeds are hidden away or buried by squirrels and forgotten, *e.g.*, acorns; seeds in fruits with sticky glands adhere to birds' plumage, *e.g.*, *Pisonia* (47: 10; 68:7) fruits carried by noddy terns on coral islets.

Man does much to assist troublesome plants to spread. Weed seeds are present as impurities with farm or garden seeds. The plants take advantage of man's cultivation, and ripen their seeds about the same time as the grain ripens.

Seeds scattered in straw and such material used in packing goods. Possibly the seeds of the milkweed have been so introduced, for the large American Monarch butterfly (109: 1) the larvæ of which feed on this plant, has recently established itself in Australia. Seeds introduced in ship's ballast. Many South African and South American pests are flourishing on the ballast heaps near the mouth of the Yarra River. Possibly some will reach farm lands.

Foxes are scattering seeds. At the summer school at Portsea, numerous fox-droppings contained many seeds of the native currant.

PLATE 48.—SOME FRUITS THAT OPEN (DEHISCENT FRUITS).
9', Seed of Hakea.

3. Seeds scattered by water:—(a) Coconuts (44: 10) floated to ocean islands; (b) Sheoak "apples" (46: 11; 60: 2^{iv}), on islands; (c) spinifex grass, a roly-poly, washed on to an island; (d) mangrove fruit washed up by waves on to tidal mud flats. (We picked up many fruits unable to germinate on the coral sand of the Barrier Reef); (e) some wattle seeds provided with a "lifebelt" to assist in floating; (f) thorn apples (48: 6) (wrongly called the castor-oil plant in Gippsland) are common along rivers; (g) docks (46: 5) on flats about streams.

4. Seeds scattered by explosion—"fairy pistols":—(a) Pods burst open and throw seeds away, *e.g.*, gorse (47: 16) and sweet pea (47: 15); (b) pansy (48: 14) and violet pinch in at the sides of the open parts of the seed-box, and squeeze the seeds out; (c) balsam (touch-me-not) (47: 13), and squirting cucumber (47: 12), squirt out seeds when touched; (d) Geranium (cranesbill) (38: 10^{v}; 66: 9) twists fruits off and jerks them to a distance. Wood sorrel (47: 14; 66: 5) ejects seeds when touched; (e) Acanthus (47: 18) and some geraniums (47: 17) have "sling fruits."

Seed dispersal is a fascinating study, and pupils should be led to realize its great importance. The Azores Islands are interesting. Of 439 native flowering plants quoted by Wallace all have seeds scattered by the wind, birds, or currents. There are no large, heavy-fruited trees, and no shrubs with hooked seeds. The flora is closely related to that of Europe. Picture a new coral island waiting to be planted. The coconut is first. Why? What others?

While plants have such beautiful devices for scattering their seeds, some Australian plants keep their seeds for years. The bottle-brush, *Callistemon*, common in gardens, shows series of fruits down the stems, each representing a year's fruiting. Fruits of as many as 23 years have been recorded as still adhering to the stem. A bush fire or a drought may kill the young or even the old plants. The seeds being retained, the plant can continue the race. Other Australian seeds (*e.g.*, wattles) have a hard cuticle, and do not germinate until the passage of a bush fire or other unusual incident. Australian seeds hold the record of longevity. Many fruit and seed specimens were preserved by Robert Brown, the botanist who accompanied Flinders

about the beginning of the last century. After being stored in the Melbourne Herbarium and elsewhere for over 100 years, some were successfully germinated by Professor Ewart and Dr. Jean White. The records of mummy wheat, though interesting, do not seem authentic. Some of the wheat has, on growth, proved to be an up-to-date variety.

CHAPTER XIII.

HOW PLANTS SPREAD OTHER THAN BY SEEDS.

Many plants spread without producing seeds. The floating water-fern, *Azolla* (49:11; 188:12), which forms a "carpet" on river backwaters and lagoons, is carried down by floods. The floating water hyacinth (188:9) has peculiar swollen leaf-stalk buoys (14:22). Another water pest is the Elodea (188:10) of Canada, which, though not known to flower in England, has spread throughout the canals and ditches of that country.

Another method of spreading is seen in the "fairy rings" (52:1[ii]) of mushroom and other fungi.

The bracken fern (50:9; 54:1), some grasses (49:2), sedges, reeds, Iris (flag) (50:10), and Solomon's seal (49:3), with underground stems, occupy new territory. The underground stem—the *"rhizome,"* is root-like in appearance. Food is stored here safely. The strawberry (22:8) and violet spread above ground; a runner is given out which roots, and a plant grows. A runner grows on again, it roots, and another plant is formed. Many lawn grasses have this creeping habit, and root down closely. The lesser couch grass (57:10) and buffalo grass (49:2), as well as the pod-bearing clover (49:1; 32:5) do so. Chickweed (16:15; 187:28) spreads likewise, rooting at intervals. Marram grass and true Spinifex, valuable shore plants, bind loose sand that might otherwise cover rich land. Blackberry (23:12) stems "arch" over, the tips touch the ground and root; other shoots grow up to arch and root again, and advance over the country. Branches of the gooseberry (49:4) root when the ground is touched, and

another plant is formed; in addition, suckers grow from underground shoots. The frond of the "walking fern" (49:5) roots when it touches the ground, and the fern "walks" on. When a tree is cut down, "suckers" often grow up. The house-leek (8) spreads by offsets.

Begonia leaves—"leaf cuttings"—are used to develop new plants. "Cuttings" and "slips" of willow, rose, and

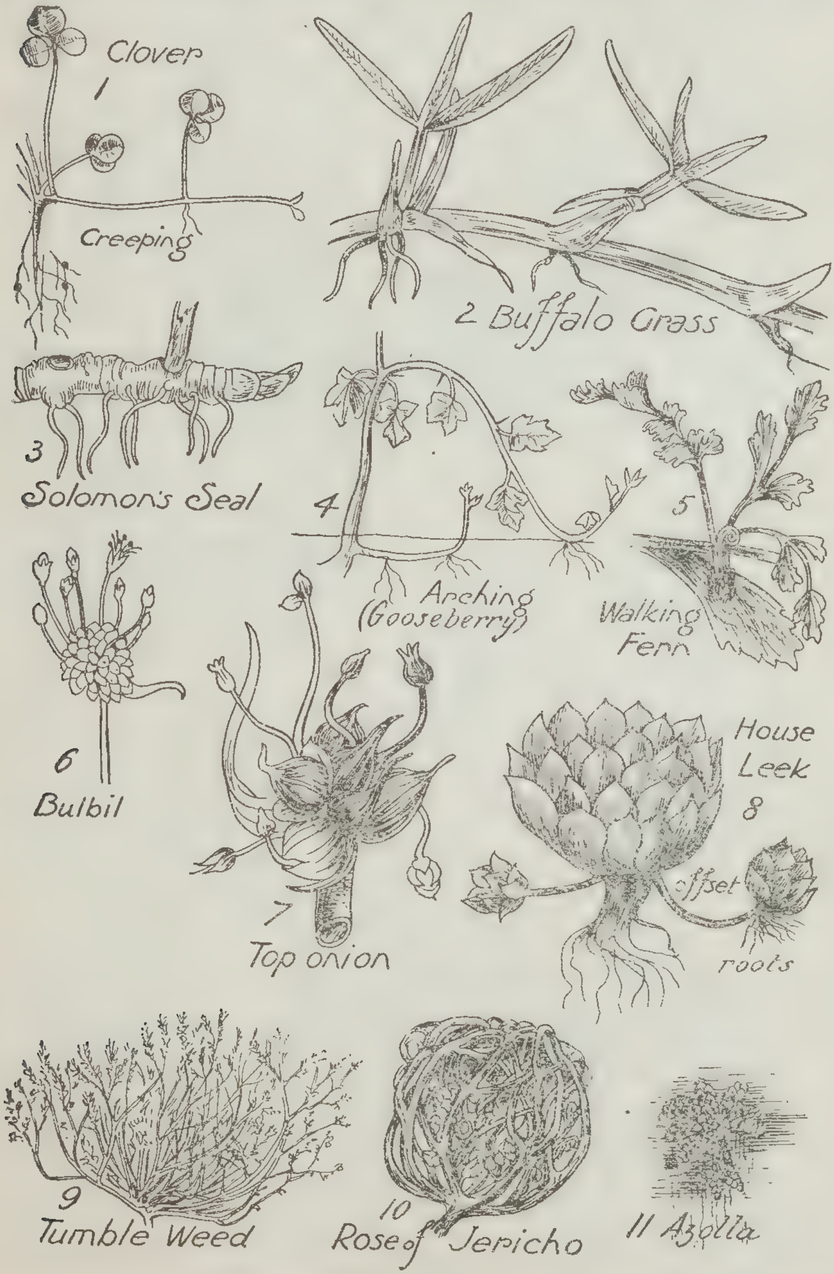

PLATE 49.—SOME PLANTS THAT SPREAD WITHOUT SEEDS

Geranium are planted, while the "layering" of carnations reminds one of the rooting of strawberries (22:8), couch grass, and buffalo grass.

Other plants detach buds, which are carried away. The "bulbils" (49:6) of the tiger-lily and the "top-onions" of the onion (49:7) plant are examples. Small outgrowths appear on the flattened stem of duck-weed (188:3) and separate, forming new plants. Sheep sorrel, knot grass, and other weeds are often spread by careless digging and ploughing. The creeping thistle has been spread by ploughing.

Other plants, such as the "tumble-weeds" (49:9) of America, in unfavorable times, dry off where the plant joins the ground, and are blown along. On reaching favorable conditions, the plant roots and develops quickly. The so-called "Russian thistle," spread as a "tumble-weed," is a serious pest in America.

In dry periods the Rose of Jericho (49:10) curls up and may blow far; at a damp place, it uncurls and grows.

The banyan tree, dropping roots from its horizontal branches, covers a large area. The mangrove of tidal flats send down many roots that anchor and spread the plants over new territory. The roots catch mud and other materials, and help to build up the land until it becomes dry. Other plants then beat the mangroves in the struggle for existence, and the land is permanently reclaimed.

The seedlings of fruit-trees do not bear fruit exactly like that of the parent trees. Hence man resorts to grafting and budding to perpetuate and increase the supply of desirable kinds. Usually he employs "resistant stocks" that suffer little from the ravages of certain pests, *e.g.*, woolly aphis, If the roots are free from aphis, the tree can be kept free.

CHAPTER XIV.

FOOD STORES.

Seeds, onions, carrots, buds on twigs, potatoes, and other plant structures sometimes grow without soil; each has stored food available.

There are few places with constant growth. The damp forests of Brazil and similar places may be such. Most

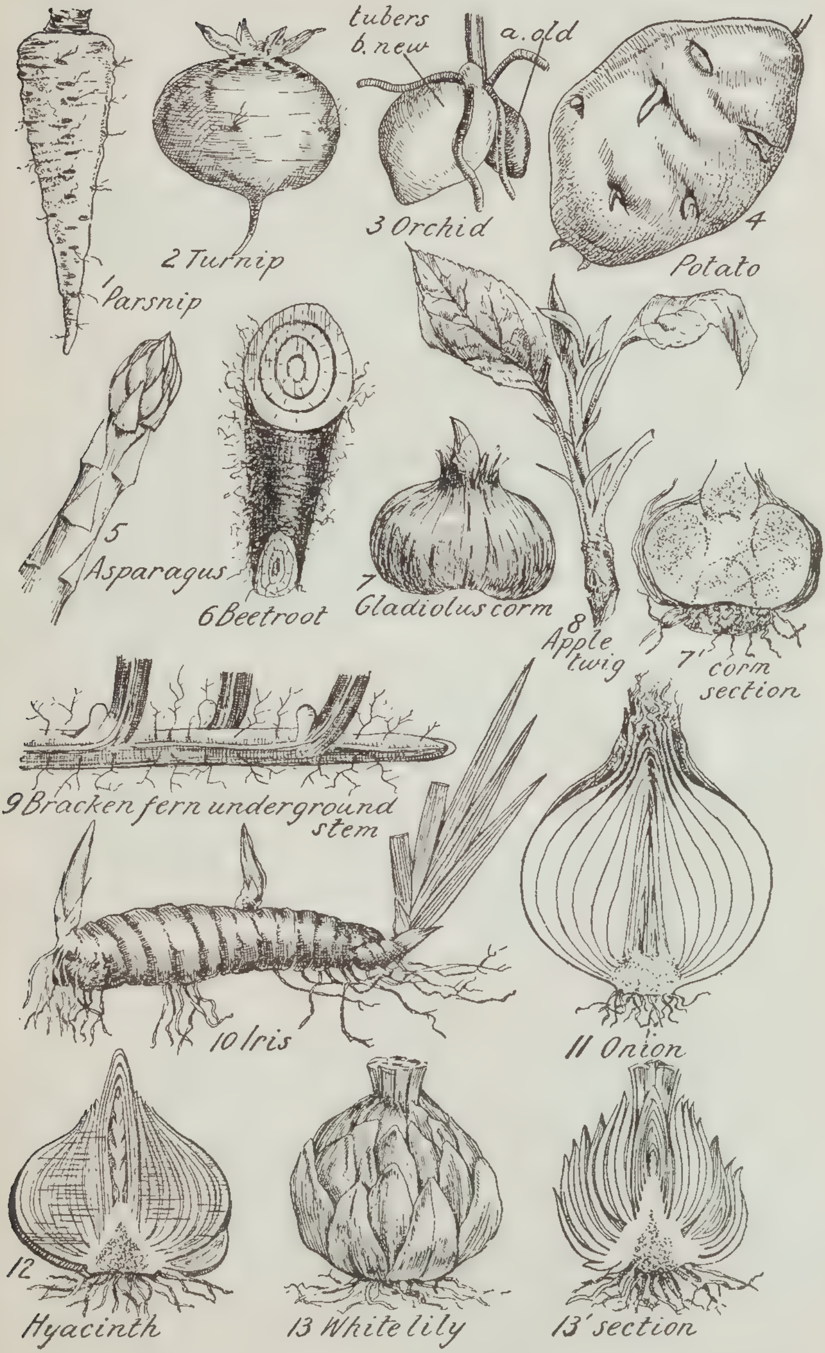

PLATE 50.—FOOD-STORES.

other places have dry or cold seasons of suspended growth. Most plants have means of tiding over unfavorable periods.

Trees in cold or hot, dry seasons shed their leaves or have other water-saving devices. Food is stored for rapid growth when favorable conditions return. Many plants storing food one season have everything ready to perfect seeds early next spring. Cabbages (30:8), carrots (21:13) and onions (50:11) do so; they are "biennial" plants, as opposed to "annuals" like grasses. Carrots and beetroot (50:6) store food in the root; turnips (50:2) and radish in a structure partly root and partly stem; orchid (50:3) and dahlia (22:4) in root stores; cabbage (30:8) and lettuce in leaves; cauliflower in modified flower structures; and deciduous trees in twig and stem; underground food stores, the parts above ground dying off, are common.

Four kinds may be noted:—(1) The bulb of the hyacinth (50:12); (2) the corm of the Gladiolus (50:7); (3) the tuber of the potato (50:4); (4) the underground stem of the Iris (50:10).

Everything was prepared last season, and with water and warmth rapid growth is made; the flower opens early to catch the flower-visiting insect before competition becomes keen. Seeds are perfected and dispersed, and provision is made for next season. The bracken fern (50:9) has an underground stem; onion (50:11) and hyacinth bulbs (50:11, 12) have flattened stems with many fleshy leaves surrounded by dry scale-leaves. Some lily bulbs (50:13, 13^1) have overlapping fleshy scales. Gladiolus and crocus have a "corm" (50:7, 7^1), a stem structure; next year's corm grows above. These plants, raising themselves each year, need replanting about every third year.

Foods are of two main kinds—(a) carbohydrates, *e.g.*, starch and sugar containing only carbon, hydrogen and oxygen, heat forming foods; and (b) proteids, muscle-forming foods containing in addition nitrogen, phosphorus and small quantities of sulphur iron and a few other elements. Seeds containing the embryo are especially rich in proteids. In stores for adult use, starch is common. The hard date "stone" (3:4) a food store of cellulose, a material resembling starch in composition, protects the young plant.

Some time ago vegetable-ivory fruits, a cellulose food-store from South Sea Island palms, reached Melbourne for umbrella handles. Being mixed with coal at the wharf, these fruits caused many reports of "fossil apples."

Sugar is stored especially in the stem of sugar-cane, the root of the beet, and the trunk of Canadian maple. Fats and oils are also stored; palm oil, castor oil, and many others are obtained from these reserves.

The amount of food stored by different plants varies greatly. Scott Elliot, in his interesting *Nature Studies,* gives:—Sago palm stores 292,320 lbs. of food per acre; banana, 242,000 lbs.; potato, 4000 lbs.; wheat, 2000 lbs.; and manioc (tapioca) 6650 lbs.

Man, a parasite on plants for food, fuel and clothing, has proved, on the whole, a highly destructive and improvident waster of Nature's bounties. Thoughtful agriculturists and plant-breeders, however, are developing the plant's capacity for storing food and resisting agents detrimental to plant life. The world's population increases and the demand for wheaten bread increases more rapidly. Many areas producing other foods are unsuited to wheat, a relatively low food storer. Agriculture giving its annual return is not possible on all lands; therefore, on alluvial areas, mining should not destroy the rich accumulations of ages for one mineral return. Many once fertile areas require geological changes and periods to fit them again for man's use.

CHAPTER XV.

GENERAL PLANT STUDIES.

A.—SEAWEEDS.

Children playing on the beach love to gather pretty seaweeds. They notice at once that these bear no flowers, though they often mistake oval structures for fruits. The different colors attract the notice of scientists as well as children, for seaweeds are grouped scientifically according to the colors—greens, browns, and reds.

The greens, *e.g.*, the common sea-lettuce (Ulva) (51:2) grow up to high-tide level, the browns (4-7) grow at mid-tides, and many are exposed at low tide; the brown coloring matter serves to protect the delicate green from injury. The brown seaweeds are often very tough and withstand the battering of waves and storm. The swollen parts are floats, not fruits. When a float is cut open, it is seen to be empty of all but air. Some browns, *e.g.*, kelp, are very strong and tough, and provide good balls for playing cricket on the beach; they are easily cut and stand knocking about.

Deeper still, exposed only at the lowest tides or not exposed at all, are the pretty red seaweeds. Some of these

PLATE 51.—SOME SEAWEEDS.

grow in fairly shallow water, and are covered over by a white coat of limy material. These are the common small jointed coralline seaweeds (51:9), often gathered from rock-pools. Some of these (*Nullipores*) help to form "coral reefs," though they have no pores or cups like the hard parts of coral animals.

Amongst the greens are the common thin green weeds of the genus *Enteromorpha* (51:1), which seems to have no good common name. Some members of the genus grow in fresh water. The name sea-grass is more often applied to the longer and broader leaved *Zostera*, which is often used for stuffing cushions, furniture, and mattresses. It is, however, not a true seaweed, but it is a member of the same family as the pond-weed, *Potamogeton*, and bears flowers and fruits. The dark green *Caulerpa* (51:3), with "beaded" surface, is common on most beaches.

The brown seaweeds are common. The shore platform is often covered with "sea-grapes" (*Hormosira*) a string of bladders (51:6) with small pits on the surface. The spores are produced in these pits. A related plant is the bladder-wrack (51:5), with bladders along the side for floats, and the spore-bearing parts are restricted to the tips of the flat leaf-like structures. The brown fan-seaweed is common in places. Kelp has already been mentioned. *Sargassum* (51:7), the weed that occupies a great eddy nearly the size of the continent of Europe in the North Atlantic Ocean, is one of the most famous. Sargassum is found here. Though seaweeds have no true stem or leaf, yet Sargassum approaches closely to that condition. The leaf is almost distinct; berry-like floats keep the weed at the surface.

Some browns are among the giants of the plant world, at least as far as length is concerned. Some are said to grow in fairly deep water and reach the surface with the aid of the series of floats; these may be almost 1000 feet long. The strength of the fine stems is surprising.

Living in moving water, there is no need for special devices for spore scattering; currents and tides can do that. Likewise there is no need for special devices for the equivalent of "pollen" dispersal. There are no bright or edible fruits and no bright flowers, in fact, no flowers at all. Seaweeds produce spores often from inconspicuous structures; the spores float or swim, and develop into new plants.

As the plants are supported in water, they have no need for big, thick stems, though there are two other necessities. The first is a holdfast so that the seaweeds are not tossed up on the beach, and the second is toughness of tissues to withstand the severe buffeting of a storm.

Living in water containing plant foods in abundance, the plant takes all it wants direct from the water. Hence there is no need for roots penetrating the soil, or for sap-tubes to convey sap up and down the plant. The roots are mere holdfasts, and very tightly do they hold. Examination of a big clump of kelp on the beach will often show the piece of rock still held by the sucker-like "root."

Though simple and lowly, seaweeds are well adapted to their environment, and there is nothing gained by a higher evolution or specialization of form or structure. Evolution does not always mean advance; it means perfect adaptation to environment. If that does not change, the animals and plants may not change.

B.—The Mushroom.

The mushroom plant (52: 1)—a fungus—has no green; it cannot manufacture food. To get a clear idea of a fungus, examine mould ($52: 9\text{-}9^{iii}$) growing on a piece of damp bread under an inverted tumbler. See the long, fine, thread-like structures. These are the feeding parts of the plants—tube-like threads that penetrate wherever there is food. In the earth round the mushroom is the "spawn"—the white, branching plant. The threads seek food in the soil.

The mushroom must spread if it is to be successful. Other plants have flowers, and, later, fruit and seeds; but here there is no flower, and where can seeds come from? Though there are no seeds, there is the equivalent—spores. These spores must be scattered to new places, otherwise the soil would be exhausted, and the plants die of starvation. Perhaps you have seen the "fairy rings" ($52: 1^{ii}$) of mushrooms, or puffballs, where the plants have spread out in all directions. In the center, suitable food in the soil has been exhausted, and the ring of mushrooms shows that only the outer parts are alive and active. Next year the ring will be larger as the plants grow outwards.

To scatter the spores, the underground plant sends up structures projecting above the surface.

Think of a puffball (52:8)—the one you kicked. Each tiny speck of the brownish-yellow powder that flew out was a spore, and you helped the plant greatly when you gave it that kick, for you gave the spores a good scattering. Still, you do not see anything like spores about a mushroom. Try

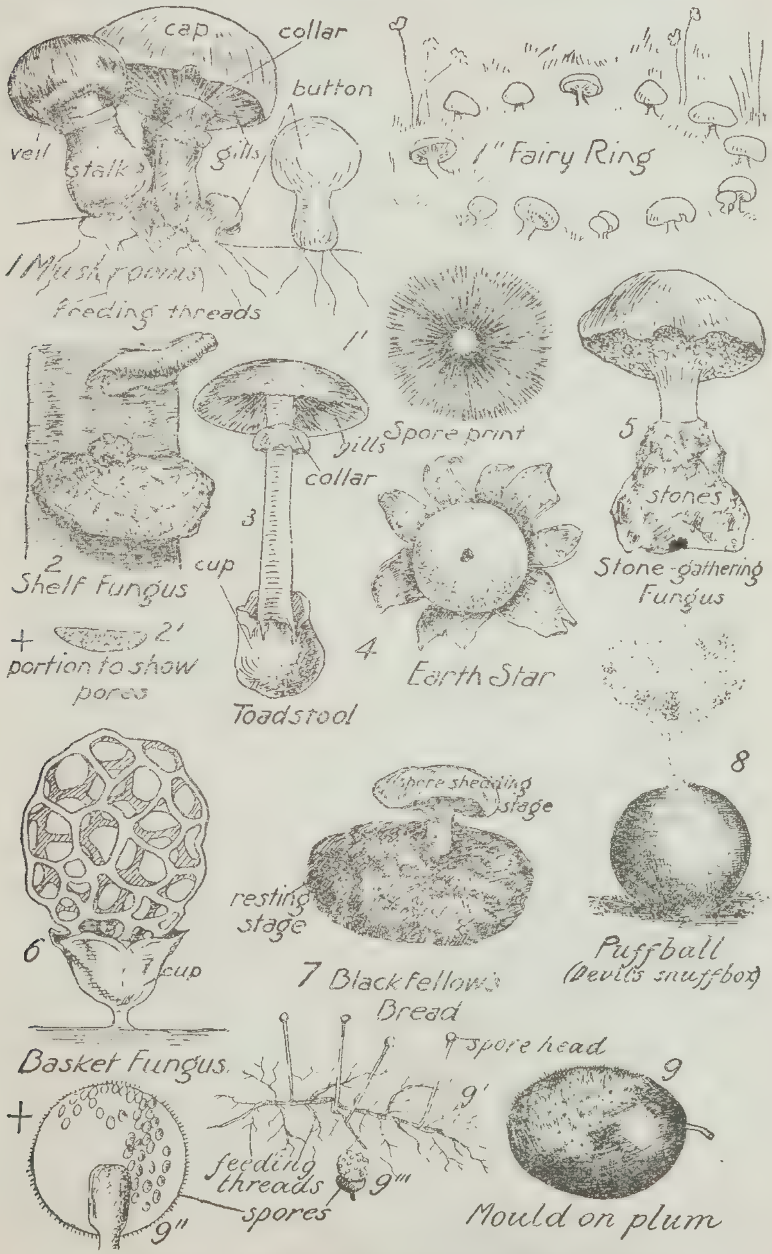

PLATE 52.—MUSHROOM AND OTHER FUNGI.

The large shelf fungus (52: 2) common on eucalypts, harms the tree. See the lines of growth on one. Examine the under surface, and see the tiny pores—hundreds of them—from which the spores have departed. On account of the pores, this fungus is named *Polyporus* (many-pored).

The "earth star" (*Geaster*), is a peculiar puffball (52:4). The outer coat splits into segments, and folds back, leaving a globular ball with a hole in the top to permit of spore dispersal. The beautiful "basket fungus," *Clathrus* (52: 6), is common in places. It resembles a puffball until it expands into a hollow network, containing a jelly-like material with the spores. Flies eating into this probably scatter the spores.

The "blackfellow's bread" (52: 7) is a fungus of great interest. The dense mass is reserve material stored away until needed; it is the resting stage in the life history of a fungus (*Polyporus*). If you are fortunate, you may see the mushroom-like outgrowth that forms the spore-scattering stage. The resting stage is a hard mass which is sometimes used for making the handles of walking sticks Specimens of "blackfellows' bread" may weigh 20 lbs.

In the very dry north-west of Victoria, the stone-gathering fungus (52: 5) binds stones and soil into a solid mass. It has a tough, mushroom-like spore-scattering stage, suggesting to many people a fossil.

While many fungi cause serious loss of grain, fruit, etc., a few are beneficial. Occasionally, dead, semi-transparent flies (29: 7) are seen. These have been killed by a fungus. The spores fall on another fly, and thus reduce the number of a disease-spreading pest. See the halo of spore-heads round the dead fly. An allied fungus grows on the grasshopper, lessening the number of plague locusts. Another beneficial animal-destroying fungus (29: 8) is the vegetable caterpillar (*Cordyceps*). The spore gains admission into the ground-living, root-eating larvae of certain moths. Another form of beneficial fungus (22: 15) lives on the roots of certain plants which have no root-hairs.

Some fungi are brightly colored; others have a most objectionable and overpowering smell, which serves to attract insects that assist in dispersing the spores. In damp scrubs, a phosphorescent fungus growing on the base of a tree is common. Its light is sometimes powerful enough to

an experiment. Place several stemless mushrooms flat on white paper. After a time you will see on the paper radiating lines (52: 1) of powder, innumerable spores. Now you have the secret of the mushroom. It may be considered the "fruit" of the mushroom plant. A high power of the microscope is required to examine the minute spores. You have seen them in the mass as radiating lines on the paper.

Having seen why the mushroom is there, let us examine it. Supporting the "cap" is a stout stalk. Both "cap" and stalk are formed from the matting together of many threads. Round the edge of the "cap" is the "veil." On the stalk, the "collar" shows where the veil bound the cap to it while the spores were being developed. When, at last, the spores are ready, the stalk has lengthened, the cap has flattened and widened, the veil has burst, exposing the delicate pink plates radiating from the stalk underneath. The plates are the "gills." They do not act as the gills of a fish do; but, since they look somewhat like the red fringes of fish gills, that name will do. The large surface of the many gills enables the plant to produce numerous minute spores, which, falling off when ripe, are blown away. Toadstools often resemble mushrooms, but grow from a "cup."

Examine again the mould on bread, or a plum ($52: 9, 9^{iii}$), or an orange, and see many little knobbed projections. These produce and scatter the spores (9^{ii}), as the large mushroom does for its underground plant.

One question must still be answered. This plant has no green, and cannot make food. How does it get food? The branching threads seek out food matter in the ground—food previously made by a green plant. The mushrooms can grow only where there is such food in the soil. Plants, *e.g.*, mushrooms, that live on dead food, are called saprophytes, to distinguish them from parasites—plants and animals that live on other living animals or plants.

Large quantities of mushrooms are grown for food. The warm tunnels of unused railways are sometimes hired by mushroom growers, who find them suitable places for rapid growth. Some day, perhaps, the disused workings in gold mines near large cities may be used for this purpose, for fungi (fun′-ji) flourish in the dark.

Some fungi are parasites, and damage trees and crops. Rust (29: 2, 3), so destructive to wheat crops, is a fungus.

see print by. It attracts insects which scatter the spores. On branches of the Kangaroo Acacia and other acacias, and on those of the wild cherry (*Exocarpus*), hard brown, knob-like structures (69: 15) are common. These are galls, due to a rust allied to the rust of wheat.

Fungi are of great economic importance. They frequently cause serious loss to wheat-farmers, potato-growers, and orchardists. The coffee-leaf disease is said to have destroyed in Ceylon plantations worth £16,000,000, while the damage to cereal crops in the United States alone has been estimated at from 25,000,000 to 30,000,000 dollars per annum. The loss in the United States for all crops has been set down at 150 millions to 200 millions of dollars annually.

Though there are many edible species of mushroom, still, these so closely resemble highly-poisonous species, and are so difficult to distinguish, that it is better not to take risks, but to eat only the common mushroom.

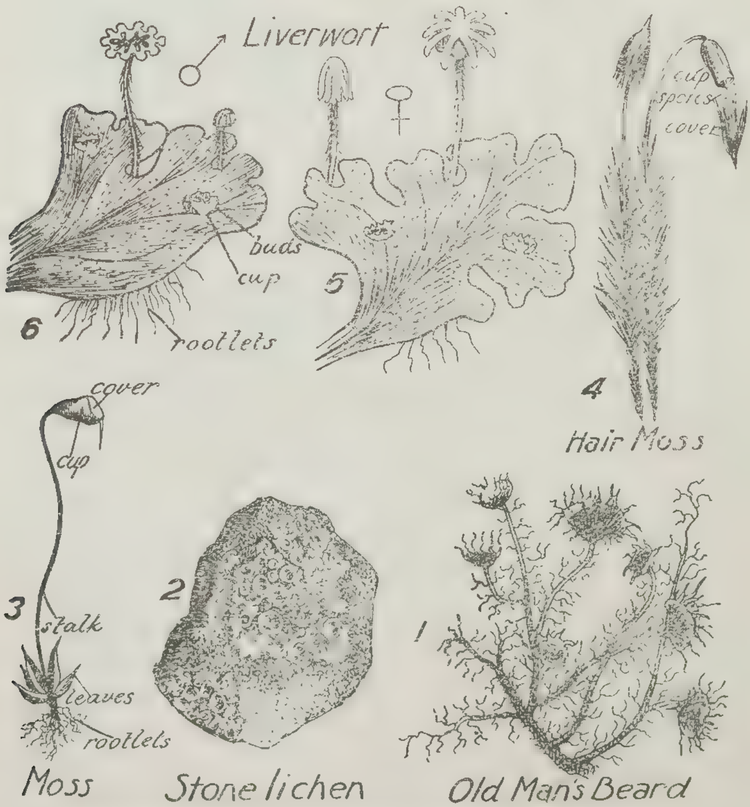

PLATE 53.—LICHENS, MOSSES AND LIVERWORT.

c.—Lichens and Mosses.

Lichens (lī′-kenz) are remarkable examples of ***symbiosis;*** a fungus lives in partnership with a lowly alga. The fungus grows round and encloses the alga, which, however, could often live free and develop even more successfully. The fungus, however, having no green, could not do so. The fungus threads collect water and soil food. The green alga manufactures starch and food; probably usually both plants benefit; certainly the fungus does. Small parts are budded off, and these can be spread by the wind, or the fungus produces spores which, if cells of the alga are present, can develop into the lichen again.

Lichens (53: 2) withstand extreme heat on a bare rock surface during the day and extreme cold during the night, and yet they thrive. They are not parasites on the rock, and probably derive nothing from it; they live on the dust that falls on the plant body, and grow only when moisture is present. By their decay, and by the action of the products of that decay, they help to break down rock surfaces, and take the first step for soil-production.

Several lichens are edible. Reindeer moss is one of these. Lichens flourish from sea level to mountain top, and from equator to the poles. They are interesting and important in the economy of nature. Some encrust stones, others grow on trees as the "old man's beard," *Usnea barbata* (53: 1), does on fences. It is claimed that the manna of the Israelites in the desert was the offsets of the edible or manna lichen, of which showers are reported at intervals.

Liverworts—fleshy, leaf-like masses (53: 5, 6) with lobes suggesting the liver—grow flat on the ground, and are anchored to it by structures that function as rootlets, gathering water and soil materials. The leaf-like surface bears cups, which contain buds. These are liberated, and develop into plants like the adult. The equivalent of seeds is also produced by the union of a particle from a male shoot with the egg-cell on the female shoot. The spore does not grow direct into a liverwort plant. About pot plants and on bare ground after a bush fire, the liverwort may often be found.

Moss (53: 3, 4) plants can easily be separated into leaf and stem. A cup containing spores is borne on a long thread or stalk. The cover, "fairy hood," "cap," or "veil,"

being removed, a lid is seen. When the lid is removed, spores fall out in dry weather from between the teeth round the inner edge of the cup (capsule). In wet weather, the cup is closed, and the spores are protected from the wet. The spores are scattered by the wind. In the days when nature was supposed to label things as medicines, hair moss, with narrow hair-like leaves, was supposed to be "labelled" for use as a hair tonic; the plants were steeped in water, which was used as a hair-wash.

D.—FERNS.

The bracken fern (54: 1) is an extremely common plant in Victoria. Unfortunately, it is too common on many dairy and grazing areas. It is, however, an interesting plant, and holds its own in the struggle for existence. Most ferns love moist and dark places. The bracken, though a true fern, flourishes on dry open hillsides.

The visible part is the "pinna," the equivalent of one leaf. There are neither flowers nor fruits. The stem grows along underground, obtaining water and soil food for the plant. This is sent up in definite water-tubes to the green parts to be manufactured into food. The food-sap is returned by definite tubes enclosed with the ascending tubes in definite sap bundles, vascular bundles. Lower plants have no sap-tubes, so that ferns are separated as "vascular cryptogams."

On each side of the dark under-ground stem is a yellow line—the "lateral line." From alternate sides the fronds or leaves arise. The bud for next season will usually be seen ready. The growing point can be easily recognized. A section of the stem ($54: 1^{i}$) shows many dark bands of strengthening material, several closed bundles of sap-tubes, and a soft, spongy food-store; rootlets are also seen.

The spores of bracken fern are borne on the back of the leaflets and are liberated in dry weather. They do not grow into a fern plant, but develop into a heart-shaped structure—a prothallus ($54: 1^{ii}$). This produces male and female cells. The male cell, the equivalent of the pollen-grain of flowering plants, swims in dew or rain to the egg cell. The equivalent of the seed grows up into the bracken fern. This plant thus shows clearly the interesting phenomenon known as "alternation of generations." This is also shown, though perhaps not so clearly, by plants lower and higher in the scale. It

is also shown by animals such as Obelia, a relative of the jelly-fish, and by insects such as Aphis. The fixed plant-like Obelia buds off a minute, freely swimming jellyfish, which produces eggs; the eggs develop into the plant-like forms.

Maidenhair (54: 5) is a favorite fern. On picnic days, along a creek or small river, it is customary to gather a bunch of maidenhair. The spores are borne by special structures on the margin of the leaf frond.

Water ferns, *Azolla* and *Marsilia,* come under notice in nature-study. Azolla (54: 3; 188: 12), with its many

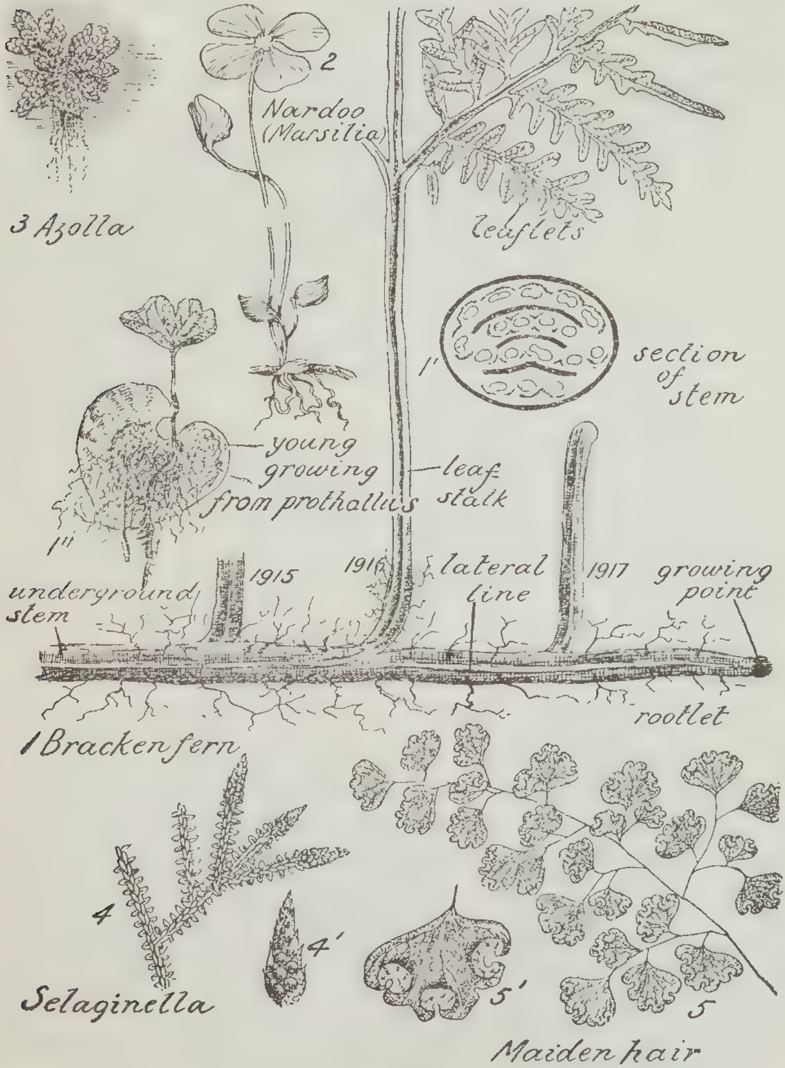

PLATE 54.—SOME FERNS, WATER-FERNS, AND SELAGINELLA.
1, Bracken; 2, Nardoo; 3, Azolla; 4, Selaginella; 5, Maiden Hair.

branches crowded with small leaves, forms a carpet which, on many lagoons and backwaters, is often red (*Azolla rubra*). It is washed down in time of flood and spread afar. The roots hang freely in the waters, which supply root-food. If pressed below, a film of water (187:26) encloses a bubble of air and returns the plant to the surface.

Marsilia (54:2; 188:7) is famous in Australian history as being the food plant of Burke and Wills when lost and deserted in Central Australia. It is a common plant throughout the crab-holes of the Mallee of North-western Victoria and along the streams of Southern Victoria; it is common on the Yarra Flats a few miles from Melbourne. The four-bladed leaf responsible for the specific name *quadrifolia,* suggests a four-leaved clover (hence the name clover fern). It is spread out on the surface of water. The small fruit-like "*sporocarps*" were used as food by the aborigines.

In the next group, the clubmosses, comes the pretty little Selaginella (54:4), often grown for purposes of decoration. The spores are borne on special branches (4^1). In the Coal Period, big trees (*Lepidodendron*) whose scaly leaves left peculiar markings, were common; fossil remains are sometimes found here.

E.—Cone-bearers.

Pines and their relatives have no bright flowers for advertising purposes, and the naked seeds are not enclosed in a seed-box. The pollen structures are scale-like (55: 1^1), and are arranged in a spiral cone (55: 1^4). The group consists of woody plants, usually with needle-like leaves.

The lower branches of the Scotch pine (55:1) drop off, leaving spreading branches near the top. The male and female flowers (1^4) are on separate parts of the same tree. The scales of the male flower have pollen on the back of them. The seed (1^5) is naked, the wing being really part of the seed. This naked seed is characteristic of the group Gymnosperm (*gymnos,* naked; *sperma,* a seed). The cone takes two years to develop. When the seeds are ripe, the cone dies, the scales separate and the seed is dispersed with the aid of its wing. The seed has many seed-leaves.

The cypress (55:2) is another cone-bearer (conifer); the seeds are borne at the inner base of a scale (2^{iii}). The scales open and the seeds fall out (2^{iv}). Pollen is borne

also on the edge of a scale (2^{v}). The leaves are reduced and scale-like; they lose little water in a dry period. The cedar (55 : 3) is also a cone-bearer. In the scattering of the seeds, the scales fall, and the axis of the cone remains.

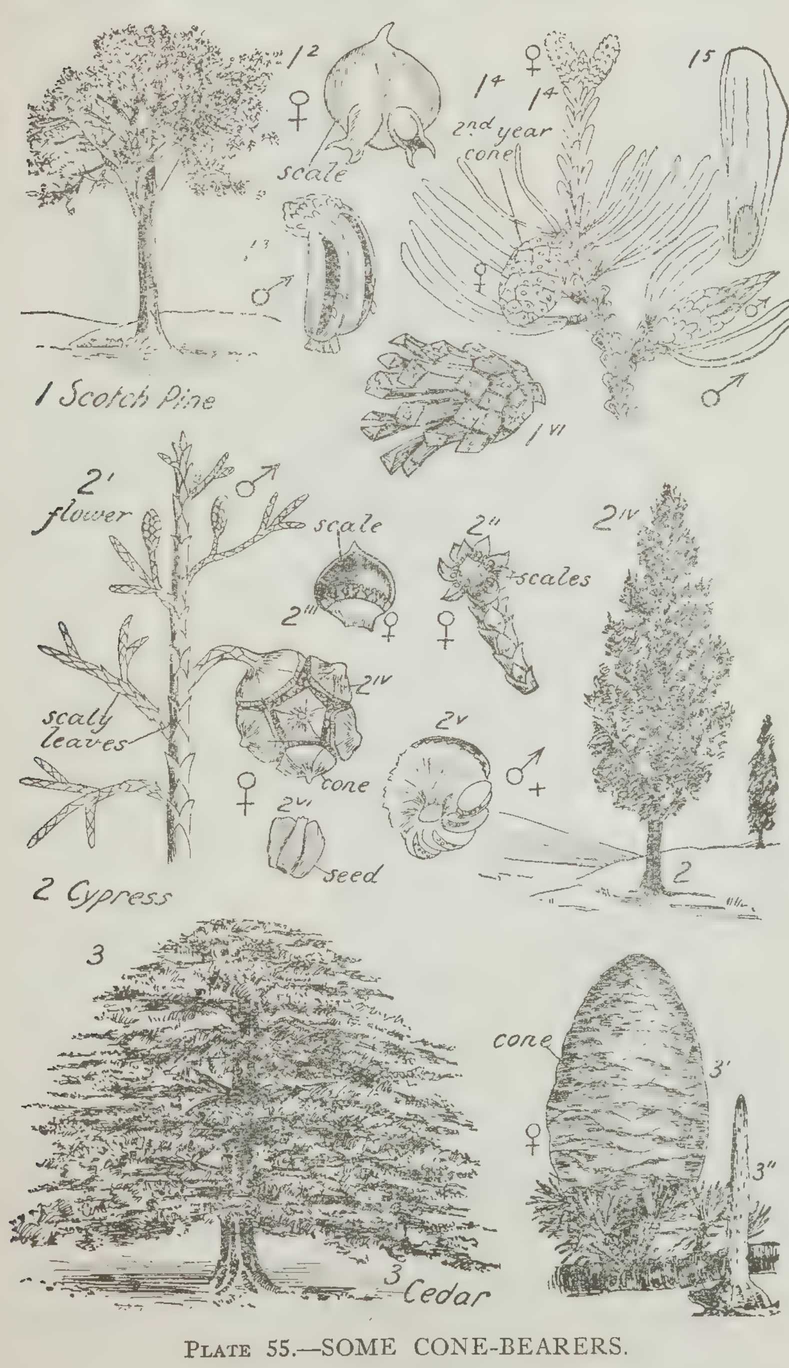

Plate 55.—SOME CONE-BEARERS.

Above the Conifers and their relations is the large group with seeds enclosed in a flask-like structure. These are classified as Angiosperms (*angios,* flask). All have flowers; they are therefore often referred to as "flowering plants."

They can be divided into two groups according as to whether the developing seed has two seed leaves or one. In the first group with one seed leaf, the *Monocotyledons,* come several families of importance in nature-study. The flowers of several of these have been described on plates 33, 34 and 35. Some grasses are considered in more detail here. Thereafter studies are made of some members of the group with two seed leaves, *Dicotyledons,* under different headings.

F.—GRASSES.

Wheat (56: 1-6) is the queen of the grasses; it can be grown even with an average annual rainfall of 10 inches.

The life-history of the wheat plant should be followed closely. The seed (3: 2; 56: 5) is really a one-seeded fruit, the fruit-coat having fused with the seed-coat. The embryo, the miniature plantlet, is placed at one end of the seed, and the large food store takes up the rest of it. The outer layers of the wheat grain (56: 5) are usually separated as the bran and the pollard.

The one seed-leaf (56: 5, 6c, d, e) has a special part (56: 5) for absorbing food to feed the embryo. The "little stem" and "little root" can be recognized in the seed (56: 5). The seed-leaf further assists the young plant by growing[1] upwards through the soil (6d). The little stem within then elongates and emerges from the end of the seed-leaf (6e).

Many roots grow (6d) down and seek food and water in the soil; the root-hairs can be plainly seen (6d, e). Likewise many stems (56: 1) can arise from the one seed. The wheat is said to "stool" or "tiller" well.

The stems have solid "nodes" and intervals between called internodes. The leaves wrap round the stem for a distance. Between the leaf-blades and the stem is a scale (14: 23; 23: 1) which serves to prevent water from getting between leaf and stem and causing decay and other trouble.

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[1]Some authorities regard this part as the sheath of the first foliage leaf (see page 9).

The leaves have parallel veins. The stem is very strong, and includes a fair amount of silica, which is a very common material in the form of sand. So much silica is there that sometimes when a haystack is burnt the stems melt and form a cinder-like mass.

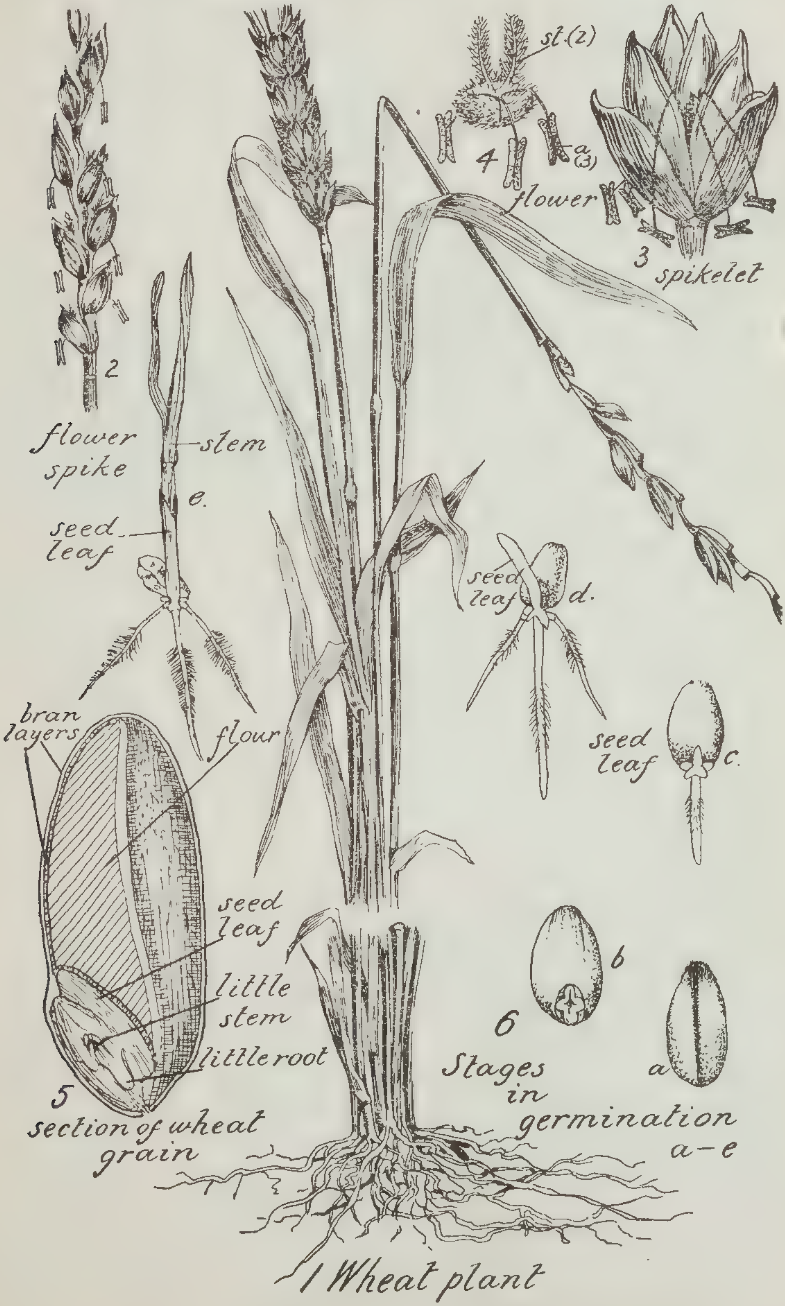


PLATE 56.—A STUDY OF THE WHEAT PLANT.

The "ear," the inflorescence or flower-spike (56: 2) consists of many spikelets (56: 3) set along the stem. Each spikelet contains two or three flowers enclosed in bracts or scale-like leaves. Each flower has three pollen boxes and two sticky tips (56: 4), as grasses generally have.

Self-pollination seems the rule, though cross-pollination by wind is usual amongst members of the order. The freely exposed and easily moved pollen boxes (56: 4) suggest wind-pollination. The large surfaced sticky tips (56: 4) also suggest wind-pollination.

Many new wheats are being bred and developed with a view to securing regular and increased yields in spite of adverse conditions. Wheats that resist drought, rusts, smuts, and various plant diseases, and that grow and produce seeds in spite of limited, heavy, or irregular rainfall are desired.

Maize, oats, rye, barley and rice are other grasses grown for grain and included under the name "cereals."

Bamboo and sugar-cane are two well-known grasses. Bamboo may be seventy feet high. Sugar is freely stored in the stem of the sugar-cane plant.

The grasses form a large family. Many are perennial; some are annual. The flower head is often a spike made up of spikelets containing clusters of flowers. Usually each flower contains three pollen boxes on long fine threads and two hairy sticky tips; the flowers are usually wind-pollinated.

Grasses are widely distributed throughout the world. So important is it to have good fodder plants, that a good grass is soon introduced into many countries and spread far. A few of the more common forms are figured here.

Prairie grass does not stand continuous feeding. It grows well in gardens or where protected from stock. It was introduced from America. Timothy is a good pasture grass. Its native home is Europe, Asia, and Africa. Cat's-tail is another name for it, but as cat's-tail has been used for the bulrush and also for water milfoil, it should not be used when there is another good name. Yorkshire fog is a grass of the moist places. Its native home is Europe, Africa, and temperate Asia. It is not so good a grass as some others mentioned. Cock's-foot grass is a favorite in the wet hills of South Gippsland; it is a useful perennial grass, a native of Europe, Africa, and temperate Asia. Meadow foxtail, a

native of the north temperate zone, is a perennial grass cultivated in some places. Annual meadow grass, or English meadow grass, is valuable in pastures as fodder; it is a native of Europe, Asia, and Africa. The rat-tail is also known in some districts as Indian grass. It forms masses or

PLATE 57.—SOME GRASSES.
4′ scale on leaf stalk.

clumps hard to dig out. It stands dry weather fairly well. Meadow fescue is a useful fodder grass native to Europe and Asia. Couch grass is a name that causes confusion. In Europe the name is applied to *Agropyrum repens,* a troublesome weed of cultivated paddocks. In Australia, the name is applied commonly to *Cynodon Dactylon,* which is called Bermuda grass in North America. The latter is a good sand-binder and stands dry weather well; it is sometimes called lesser couch grass (couch rhymes with pouch). Marram grass, the famous sand-binder, has been introduced and extensively planted on the seashore to bind the loose sand. It is a native of America and Europe. *Paspalum dilatatum* is a famous perennial fodder grass that stands drought well. It has been extensively planted in warmer districts. It is a native of the Argentine and of Uruguay. Buffalo grass is the St. Augustine grass of North America. It is extensively planted for lawns; it is browned by frost in winter. The warmer parts of Africa and North America are its native homes. Kangaroo and wallaby grasses are two well-known native grasses. The former is a desirable pasture plant, but is eaten out on heavily stocked country. It is said to produce few fertile seeds.

G.—TREE STUDIES.

Trees should figure largely in a nature-study course. The oak, elm, and plane are well known ornamental trees.

The oak (58: 1-1^4) is a valuable source of timber in Europe. Here it is grown for ornament. There are many kinds of oaks grown in the parks. Some are evergreen; some are entirely deciduous; some drop most of the leaves, though a few are retained by the Portuguese oak throughout the winter. The German oak retains its brown leaves throughout the winter. Male and female flowers of oak-trees are borne separately on the same tree. The male flowers are long, slender catkins (1^2). The female flowers (1^3) have a characteristic cup at the base. The fruit, a nut, is an acorn. In germination it resembles the broad bean.

The common elm (58: 2) provides good material for nature-study. The wind-pollinated flowers (2^2-2^4) appear before the leaves. The tree with expanding buds has a distinct reddish tinge before the bud-scales fall. The flowers, which grow in clusters (2^2-2^4) have both pollen boxes and

sticky tip together. The fruits (58 : 2^5) are one-seeded, with a flat wing on each side; these are scattered widely by the wind. Numbers are produced each year, yet it is seldom indeed that a seedling is observed, though suckers sometimes

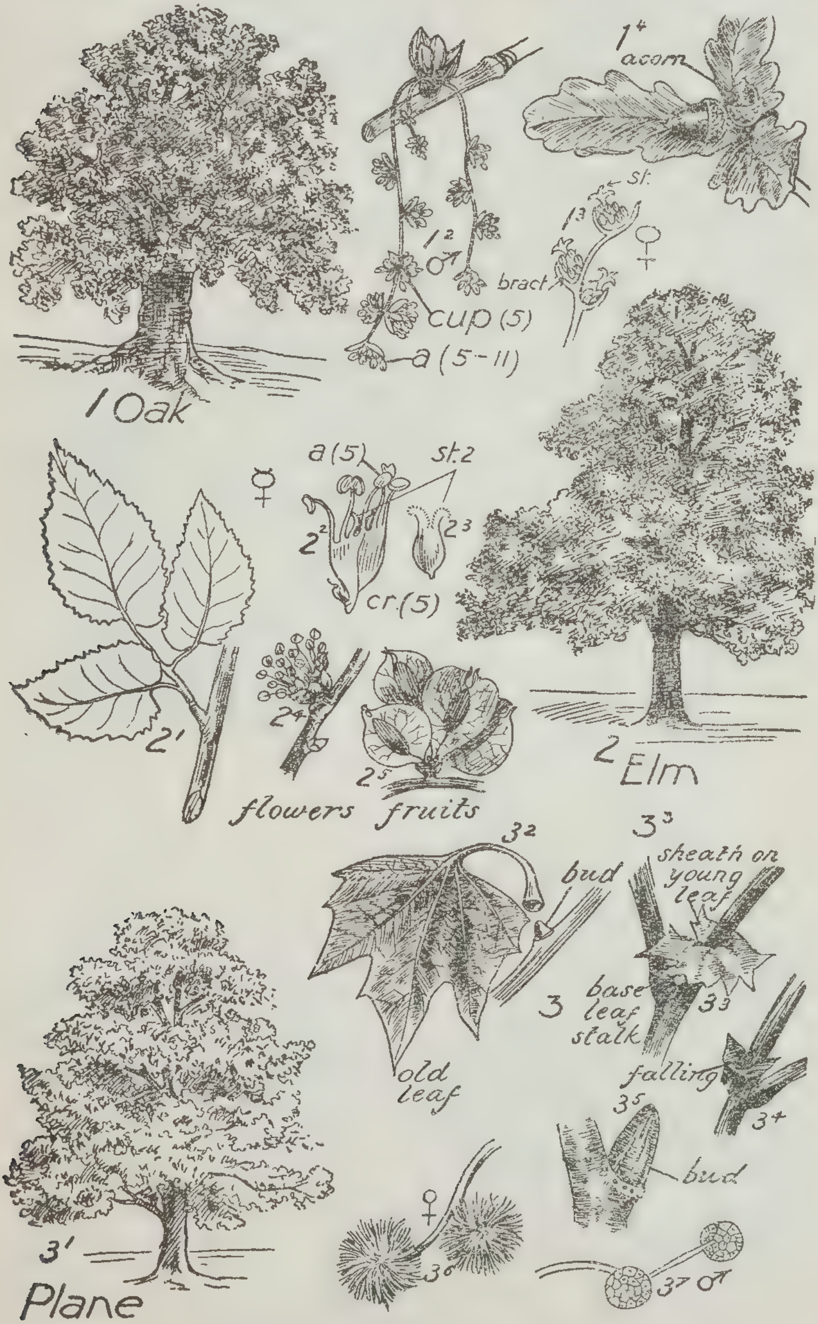


PLATE 58.—OAK, ELM, AND PLANE.

grow up from the roots. The serrated leaves form interesting leaf mosaics (11:2); the oblique leaves (12:9) are always unsymmetrical.

The oriental plane (58:3) is a favorite tree. The large palmate leaf, with its swollen cushion (3^2) at the base, completely hides the large bud (3^5) in its waterproof covering. The young leaf has a remarkable overcoat or sheath (3^3, 3^4), which encircles the stem for a short distance, and is then spread out flat like a leaf; this soon falls off.

The male (3^7) and female (3^6) flowers are borne on separate stalks, usually two flower heads on a stalk. The female flowers (3^6) can be recognized by the more hairy appearance of the many sticky tips. Planes are wind-pollinated. The hairy seeds are scattered by wind on the breaking up of the "buttonballs" usually in early spring. Dr. Shufeldt has recently published a photograph of seven balls on the one stalk. Two seems the usual number in Australia. The hairs that serve to protect the young leaves until the tissues harden are said to cause trouble to many people by irritating the mucous lining of the breathing passages.

Willows of various kinds are commonly grown in damp places or along water-courses. The weeping willow (24:7) is often grown to prevent erosion of river banks. Cattle are fond of willow shoots and the trees are usually trimmed off horizontally at the height cattle can reach. Other willows are much grown for basket twigs and for cricket bats. Poplars and willows make up one family. The pollen boxes and seed-boxes are on different trees. The flowers are borne in catkins; those of the pussy willow are often seen in nature-study rooms. The flowers ($59:1^{ii}$) of the willow are insect-pollinated and therefore have nectaries to secrete honey, though there are no bright advertising colors. Still, few flowers are available when willows bloom and bees visit them freely. The male trees have a sweet scent. There are usually two pollen boxes in each male flower. The seeds ($59:1^{iii}$; 46:20) have silky hairs, and can be carried far.

Poplars (59:2) are wind-pollinated, and therefore the flowers have no nectaries or scent. The leaves usually have long, slender leaf-stalks ($59:2^{i}$; 14:18) so that they adjust themselves readily to the wind, and are seldom torn. The

least breath of wind shakes them, hence the saying to "tremble like an aspen," which is a kind of poplar. The catkins in general resemble those of the willow as do the seeds

PLATE 59.—TREE STUDIES.
1, Willow; n, nectary; 2, Poplar; 3, Pepper Tree (*Schinus molle*), fruits reduced.

and fruits. When the small seeds with their silky hairs are being liberated, a poplar tree will sometimes cover a roadway as with a fall of snow.

The pepper tree, *Schinus molle* (59: 3) a native of Peru, is a favorite ornamental tree in the dry parts of Victoria. It is a rapid grower. Pollen and seed-box flowers are on separate trees, though differentiation is not quite complete. An occasional fruit is found on a male tree, the flower of which contains ten pollen boxes. The female flowers contain ten white dots representing reduced pollen boxes. The trees fruit freely; the small bright red fruits (3^{iv}) are conspicuous, and are much eaten by many birds in winter. The drooping compound leaves ($59: 3^{i}$) have many leaflets and allow light to penetrate to leaves in the center of the tree.

Native trees are well worthy of study. The eucalypt is a source of much wealth, material and otherwise. Easy recognition in the field seems impossible. Over seventy species are now recognized for the State of Victoria alone. The essential oil obtained by distillation is said to be one of the best guides to identification. Great variety of form and appearance under different conditions is usual. In drought, the brave old gums stand apparently unconcerned. Doubtless they have had something to do with developing the Anzac quality and capacity for "sticking it."

The fruits are not edible, but the honey-bearing flowers make the eucalypts great "bird trees." The numerous species of honey-eaters and honey-eating lorikeets (parrots) and wood-swallows find out flowering gums even in the heart of the city. The parrots often nip off the flower after extracting the honey, so that the ground under the tree is often covered by a cream carpet. (Gang-gang cockatoos nip off twigs.) This prolongs the flowering season, as our parrots and cockatoos discovered before expert gardeners were known here. Just as shearers, starting in the north work down Eastern Australia, so swift-flying, screeching lorikeets in great flocks follow the flowering gums south through district after district.

The leaves of many eucalypts, *e.g., E. globulus* in particular, change (17: 7) from oval or even circular, stalk-less, paired leaves, placed horizontally, to sickle-shaped leaves with distinct leaf-stalk, growing singly and vertically.

The eucalypt leaves yield valuable oils of many kinds. Possibly the oil forms a vapor which protects the tree in hot weather.

The flowers are well protected by a hard cap (1^1) hence the name eucalypt, from (*eu*, well; *calyptos*, covered).

PLATE 60.—SOME AUSTRALIAN TREES.
1, Eucalypt; 2, Sheoak; 3, Cootamundra Wattle.

Numerous pollen boxes (1ii) on long threads do the advertising for insects and birds.

Many kinds of eucalypts drop the bark (24: 11) instead of the evergreen leaves, though the ironbark retains the bark which may be several inches thick. Sheets of stringy-bark are much used by pioneer settlers for roofing and building.

The timber of many eucalypts is of much value for high-class furniture and for work requiring great strength and durability. The eucalypt is also playing its part in matters of health; blue gums are being freely planted in swampy, malarial regions in other countries.

The sheoak (*Casuarina*) (60: 2) is one of Australia's "leafless trees." It has the silver grain "medullary rays" very strongly developed, and somewhat resembles oak, but why called sheoak and bulloak it is not easy to say. The bushman almost invariably calls the female tree a bulloak, and the male tree, a sheoak. The sexes are separate, except occasionally in the shrubby *C. distyla,* when both male (2ii) and female (2iii) flowers, which are wind-pollinated, occur on the same plant. The grooved branches are jointed and can easily be pulled apart, the remains of the true leaves appear as small teeth (2vi) round the cavity of a joint. The male flowers (2ii) hang at the end of the branchlets, the pollen boxes hanging well out. The female flowers (2iii) are of a deep-red color and appear hairy. The fruit (2iv) is a fairly large, cone-like structure. When ripe, the valves open, and the winged seeds (2v) are liberated. The drooping branchlets of some of the species give a feathery effect, suggesting the plumage of the emu or cassowary (*Casuarius*).

The wattle or Acacia (60: 3) is famous for its golden blossom, which in spring almost hides all trace of leaves. Acres of wattle in full bloom form a sight to be remembered. That Australia is a land of scentless flowers is a libel in the presence of the Boronia and the wattle, which have fine strong perfumes.

Some wattles have feathery leaves, each compound leaf and each leaflet also being like a feather, hence they are called bipinnate. The leaves have glands (16: 7), the use of which seems doubtful. These glands are usually said to secrete honey for ants, possibly to keep pests away, but of all trees the short-lived wattle seems most subject to pests.

Many wattles are leafless, but have large phyllodes, flattened leaf-stalks (17: 5; 18: 2). The flowers of some kinds form a long catkin-like structure; of others, a round ball. Each ball is a bunch of flowers (60: 3). The long, slender, white sticky tip is ripe early, and afterwards is less conspicuous; the many small pollen boxes on golden threads project like brushes, then expand to make an even sphere. The crown and cup of each floret are inconspicuous. Some florets have no seed-box. Some species or other of Australian wattles is in flower every month in the year. The bark is famous for its high percentage of tannin. Thousands of trees are stripped of their bark annually, and, of course, die. The fruit (3^{v}) is a pod. The seeds, provided with a hard cuticle, last for years in the ground. Years after wattles have disappeared from the place, if the ground is dug or a bushfire passes, a grove of young wattles may appear. The wood of the blackwood is second to none for art furniture and high-class fittings. There is a movement to have

PLATE 61.—PITTOSPORUM AND ROBINIA

the wattle chosen as Australia's national flower; the eucalypt is undoubtedly Australia's national tree.

One of the sweetest-smelling of all plants is the sweet Pittosporum (*Pittosporum undulatum*), the hedge plant that is being established in many gardens in its native State.

The sweet Pittosporum (pit-tos′-po-rum), is a worthy tree (61: 1) about parks and gardens, and a fine hedge plant. It provides good material for nature-study. The long, oval leaves usually grow eight or nine in a circle (61: 1^{ii}). The young leaves are light in color and have a highly varnished surface, reflecting the heat of the sun and protecting the delicate tissues. The buds of this evergreen provide good studies. The flowers are especially interesting. The female trees fruit freely. At the base of the urn-like seed-box (1^{iv}) are five whitish dots, representing the reduced pollen boxes. The male flowers have five pollen boxes and a well-developed seed-box, which, however, seldom develops into a fruit, for it is indeed rare that a fruit is found on a male tree. The orange-colored fruits are conspicuous, and one species is called the native orange.

The fruits split open, and the sticky seeds are eaten by birds; even the introduced song thrush in winter partakes of the food offered, and doubtless in wiping the sticky seeds from the bill, assists in scattering the seeds. In its native gullies the seeds often germinate in the side of a tree fern. The root then grows down to the soil and the tree can live independently of the fern.

The large deciduous *Robinia* ("Acacia") is a favorite ornamental tree (61: 2) in country districts. It is not an acacia, though popularly called the acacia locust in North America. Its scientific name is *Robinia pseudacacia.* The big compound leaves with rounded oval leaflets and spiny stipules give pleasant shade in warm weather. They go to sleep at night (61: 2^{i}). The many clusters of creamy to white flowers are a fine ornament. Sometimes the tree is wrongly called the laburnum, but the laburnum has a compound leaf with three leaflets and yellow flowers.

H.—The Apple and Grape.

The apple provides a fine series of studies (62: 1-11). The shapely tree itself, with its stout trunk, the twigs show-

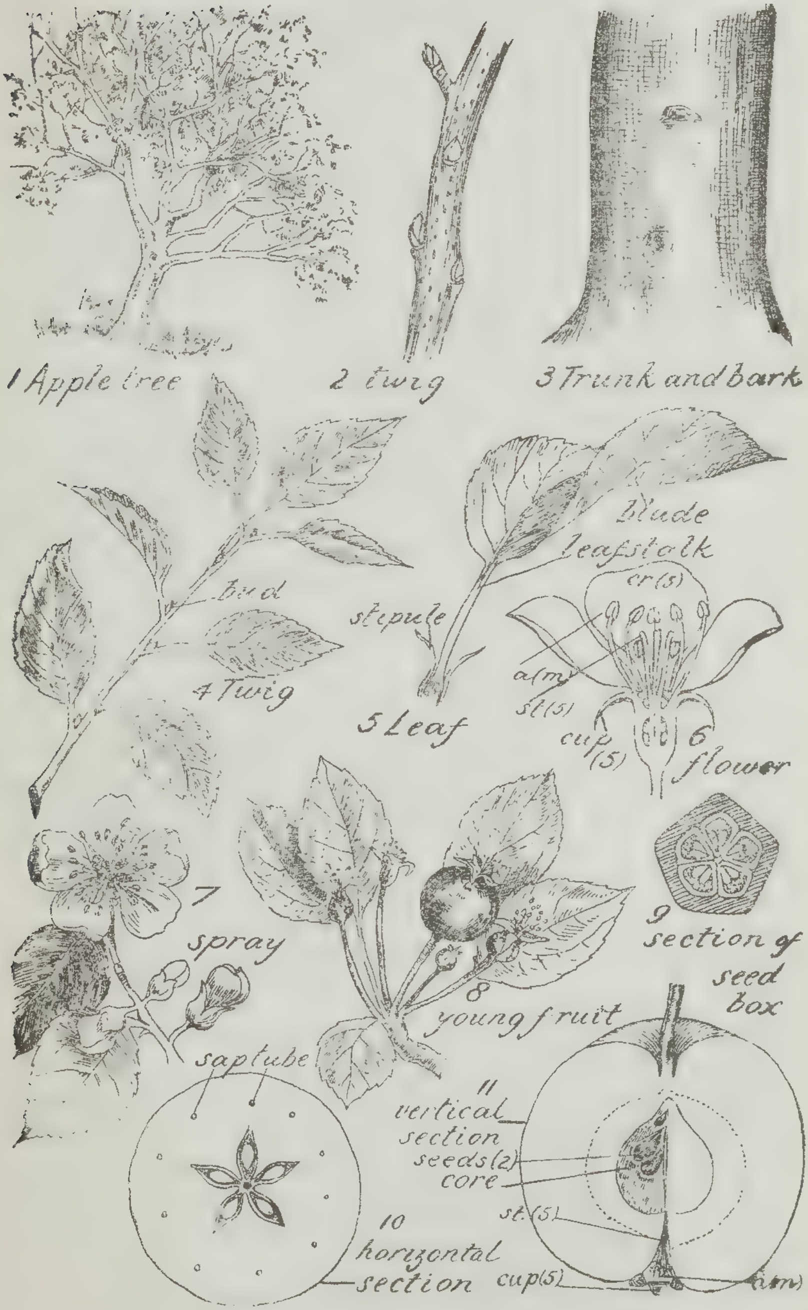


PLATE 62.—THE APPLE TREE.
The dots on 2 represent lenticels (breathing pores).

ing many lenticels (breathing holes); the buds (4, 7, 8) some with leafy shoots only, and some with leaf and flowers; and the flowers (6, 7) having many pollen boxes and five sticky tips, one for each division of the "core," are studies for winter and early spring.

The finely serrate simple leaves have stipules when young (62: 5; 50: 8) but lose them as they get older (4). The bright color of the flowers (62: 6. 7) and the buzzing busy bees are pleasant on a sleepy sunny spring day. The "apple snow" on the ground as the petals fall and the young apples (62: 8) develop; the bitter taste of the young apples repulsive to all animals but the young school boy; the bright attractive colors of the mature fruit with the pleasant smell and attractive flavor, are associated with old memories.

There are seeds, one, two, or possibly three (11), in each of the five horny divisions of the core. The fall of the leaf, its work being done, should also be studied; the student should note the marvellous providence in the preparation of

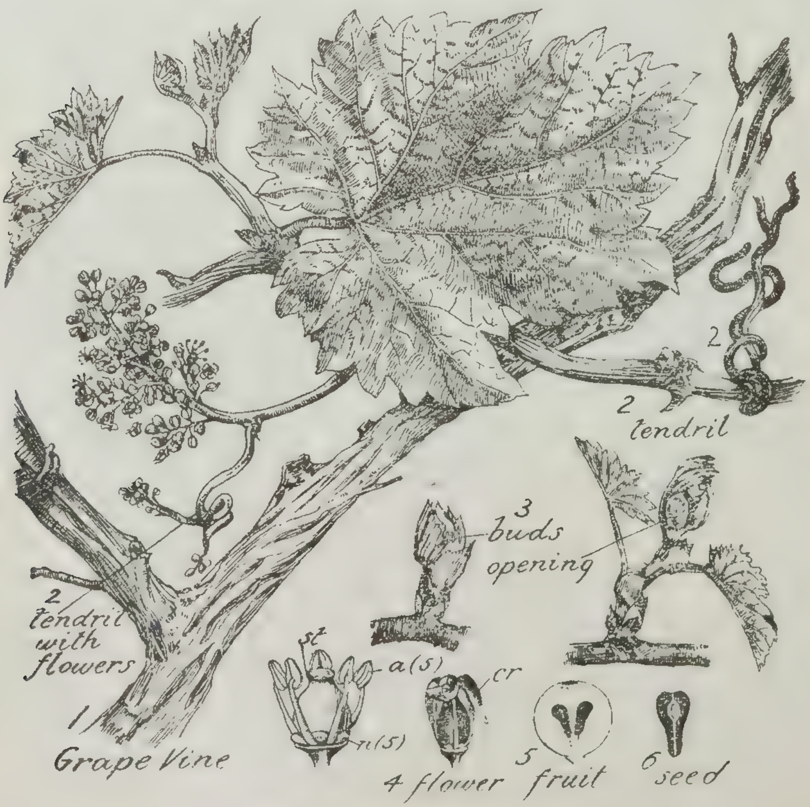


Plate 63.—THE GRAPE VINE.

the buds, leaf, and fruit for next season, and the safe passage through the stress and danger of winter.

The cause and remedy for bitter pit, a serious disease of the apple, are still under investigation. The high commercial value of this dainty article of food combined with its seasonal changes make the apple-tree one of the best of subjects for a series of seasonal studies following the annual development of the tree and the marketing of its produce.

The grape vine (63: 1-6) is another plant of economic importance that will provide a series of seasonal studies. The rugged stem, with its many tendrils, spreads the plant far and wide without the expenditure of material and energy on a tall stem to support the weight of leaves and fruit.

The "woolly" buds (63: 3) expand into shoots, bearing leaves and bunches of flowers. The remarkable flower (4), with much honey but no bright parts, has a peculiar crown which, instead of advertising, protects the essential structures until all is ready; it is then pushed off, exposing a sticky tip and five pollen boxes to the visit of bees and other insects. The fruit (5), a berry, has two hard seeds, "stones" (6), almost incapable of damage from animal teeth. The commercial products of the vine could also receive consideration in vineyard and fruit-drying districts.

1.—Potato, Tomato and Pumpkin.

The potato (64: 1) is almost as important in nature-study as in the daily life of the people. It helps to impress the lesson that "things are not what they seem." Many find it hard to believe that the potato (50: 4) is a stem food-store and not a root. However, the proof is clear. The buds are arranged on the potato (31: 3) in the same way as the buds on the stem of a shrub or tree. The flower (64: 1^{ii}) suggests the tomato flower; the fruit (64: 1^{iii}) suggests a small tomato, too, for potato and tomato (64: 2) are cousins. Grown from "stem cuttings" for many generations, it is important to secure new plants from healthy fruits, for plants grown continuously from cuttings, e.g., banana, sugar cane, and potato, deteriorate unless renewed by vigorous seeds produced by cross-pollination from different plants.

The tomato called also the "love apple," is related to the potato; but, while the potato has been selected for its underground food stores, the tomato has been developed for its

fruit. This has increased greatly in size, and has become much smoother in the skin. The tomato flower resembles that of the potato. If pollen is short in tomato or apple, one side of the fruit does not develop; distorted fruit results.

PLATE 64.—POTATO, TOMATO, AND PUMPKIN.

The small "black nightshade," a common weed of garden and field; the rare "deadly nightshade"; the African box-thorn, a common hedge plant; and the apple of Sodom have flowers and fruits somewhat similar to those of potato and tomato. The tobacco plant and the thorn apple, very common along Gippsland rivers, where it is wrongly called the castor oil plant, are in the same family (Solanaceæ).

The pumpkin (64: 3) is a good study for a plant life-history. The germination has already been treated (2: 2). The rough, fluted stem has climbing tendrils (28: 5), though it more often runs along the ground than climbs. The tendril (28: 5; 64: 3^{ii}) is coiled one way for half its length and the reverse way for the other half so that it can act as a spring and pull out almost straight without letting go its hold.

The leaf is large. The pollen boxes and seed-box are in separate flowers on the same plant. The female flower has a complicated sticky tip that misleads some people, who mistake it for pollen boxes; but a glance will show the large seed-box ready to become the pumpkin. The pollen boxes in the male flower are gathered into a central column. Some call the pumpkin a vegetable, not a fruit; but vegetable is not an exact word. A vegetable may be seed, as in the case of peas and broad beans; root, carrot and parsnips; leaf, cabbage and spinach; leaf-stalk, celery; stem, artichoke and potato; flower, cauliflower; or fruit, tomato, vegetable marrow and pumpkin.

J.—The Dandelion.

The dandelion (65) is a splendid subject for nature studies. In many schools, the plants are grown from seed to seed, and are studied at each stage.

The dandelion plant is common, *i.e.*, it is successful in the struggle for existence. The common plant has points of advantage that enable it to beat the rare, and is usually better for our purpose. Common plants beating the rare are usually more wonderful; at least they are better fitted to live under the conditions that exist.

The plant itself is worthy of study. The leaves form a rosette (65: 2) with the inner leaves shorter and more erect, the outer longer and flat on the ground. The gaps in the leaves suggested the old idea of the cusps and points on a lion's tooth, so that the name is a corruption of the

French *dent de lion.* Light passes through the gaps to the lower leaves. The stem is very short bearing the radical leaves (11 : 10) above and the root below. The root (65 : 1) is long and fleshy, bearing rootlets. It is a holdfast, and is a food-store as well as a water supplier. When any part is damaged, a white, milky fluid (*latex*) exudes. This is concerned with preventing harm by bacteria and other enemies.

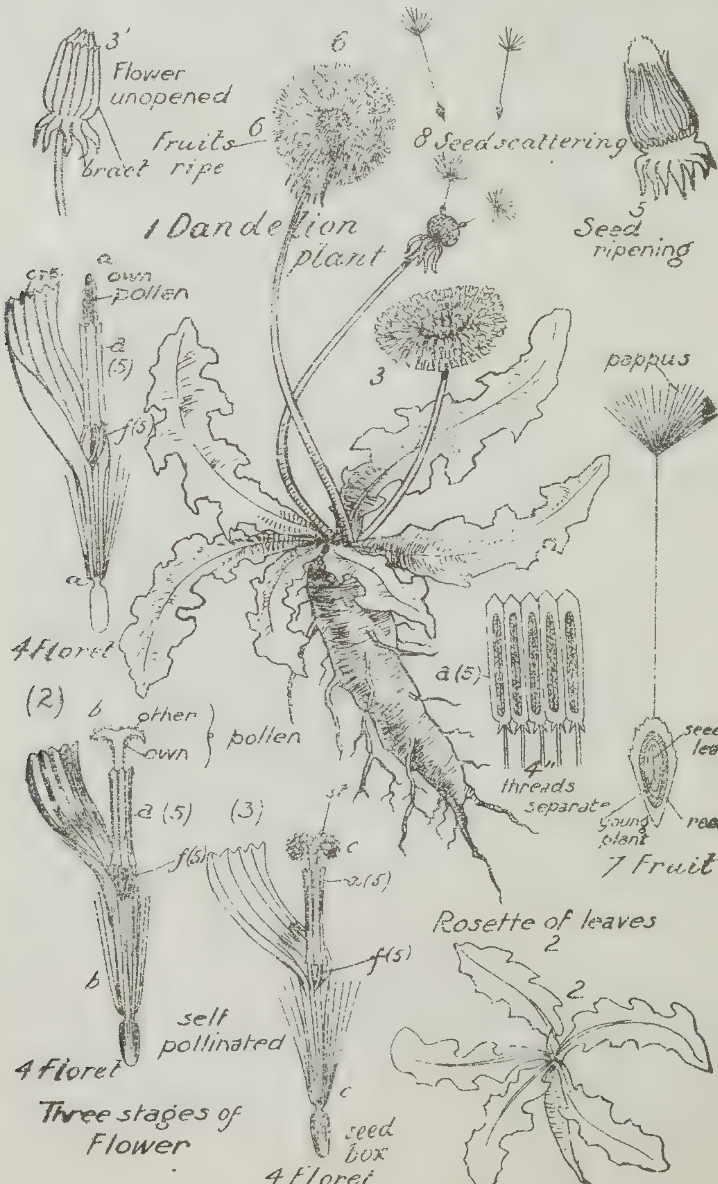


PLATE 65.—THE DANDELION.
2, 3, 4.—f, Threads (Filaments).

The so-called flower (65 : 3) is a head or bunch of flowers. The many small, strap-like florets (65 : 4) are similar; each is a perfect flower, with all the parts of a typical flower. Until ready, the flower-bud is usually low down. When ready to expand, it is pushed up on its long flower-stalk, the green bracts ($65:3^1$) bend back, and each floret has room to expand; each has a seed-box below surmounted by a long, narrow structure, which, near its summit, projects from a collar really formed of the five pollen-boxes (4^{ii}), all joined together, the five threads being separate just below (65 : 4a, b, c). The pollen boxes open inwards, and the pollen grains are shed inwards; the top of the seed-box (65 : 4a) growing up, lifts up the pollen of that floret, and visiting bees take some; this is the pollen-dispersing stage.

In the next stage (4b), the top of the seed-box structure has divided, and the two parts are spread out. This is the sticky tip ready for cross-pollination; its own pollen is below and self-pollination is not possible at this stage. If (4c) cross-pollination has failed, the two sticky tips grow round until they take some of the plant's own pollen. The plant apparently acts on the principle that half a loaf is better than no bread, and poor seeds are better than no seeds. The plant has fallen back on self-pollination. The contents of the pollen-grain grow down to fuse with the baby seed in the seed-box below. The crown of common flowers is represented by the long, yellow, strap-like structure. The five teeth at the end of it indicate that five petals have joined into one structure. The hairs represent the cup. The green leaf-like "bracts" on the back of the flower head are not the cup (*calyx*); they are the involucre. In wet weather and at night, they close the flower and so protect the pollen.

After fertilization, the flower-head is lowered while the seeds are being perfected. The part of each floret between the hairs and seed-box elongates; the cushion of the flower-head becomes convex, causing the fruits to make the interesting balls called "clocks" by the children, who sometimes blow on one to see if "mother wants me." The hairs are now useful in scattering the many one-seeded fruits (65 : 7). The top of the seed-box (4 : 7) has spines. As the fruit rocks in the wind, it sinks down amongst the grass stems, the spines prevent its withdrawal; it rocks and sinks lower, and

radicata, the flat-weed or cat's-ear, so called from a fanciful resemblance of the leaves to a cat's ear.

K.—Wayside and Common Plants.

One of the commonest of weeds in the early spring is the shepherd's purse (66: 1), a regularly self-pollinated annual not depending on insect visits. It may perfect one set of seeds before other plants begin the year's work. The basal leaves form a rosette with leaves tapering inwards; the leaves of the wiry stem are arrow-shaped. The flowers are small and inconspicuous. The seed-box is an inverted triangle with numerous seeds arranged about a central partition. The fruit splits open on each side of the central axis and the seeds of this introduced plant are shed.

Clovers (66: 2) of many kinds are common amongst lawns, on waysides, and in pastures. The stem (49: 1) runs along the ground and roots down firmly at intervals. The compound leaf, with three leaflets, gives the name *Trifolium* to the genus. A modification (through the French) gives the name trefoil. One kind (burr medick) has hooked burrs (32: 6); the small yellow flowers (32: 6) are of the pea type; the fruits of one kind make a light, woolly ball (66: 2); white clover flowers (32: 5, 5^1) have been described.

Chickweed (66: 3) is another of the early weeds of the garden. It likes damp weather, and has a series of hairs (16: 15) down the stem, "forming a staircase for rain-drops (187: 28) to roll down the stem without wetting it." Professor Ewart says it seeds freely throughout the year, and may have six generations in the year, producing, if all germinated, about 320,000,000,000 plants in one year. It is, however, easily treated and does not stand drought.

The scarlet pimpernel (66: 4) is becoming a very common weed of garden and field. It is a small annual with square, weak stems, and opposite stalkless leaves (12: 17); with one scarlet (or, rarely, blue) flower on a long stalk above each leaf. It is also called the shepherd's, or poor man's weather glass, because the flowers close in damp weather. The seed-case (48: 7) is spherical, and the top half lifts off, allowing the seeds to be dispersed. It has narcotic properties sufficient to cause the plant to be classed

the seed is planted in the ground, there to develop in due course and repeat the interesting life-history. Altogether, the common dandelion is one of the most interesting of plants. A plant often called the dandelion is *Hypochaeris*

PLATE 66.—SOME WAYSIDE AND COMMON PLANTS.

as a poisonous plant if eaten in considerable quantity. It is an introduced plant often mentioned in literature.

The South African wood sorrel (66:5) with large, yellow flowers and notched leaflets, is very common. Professor Ewart classes it as a "highly obnoxious weed, especially in gardens." The root-stock is fleshy and produces bulbils freely. On account of the presence of oxalic acid in the leaves, it is often left by grazing cattle, and is sometimes called soursobs. The leaves take a sleeping position in cold or dry weather (17:2) and at night (27:3). The seeds (66:5) are shot out when the seed-box is touched.

The ribwort (66:6) is a perennial with a rosette (11:4) of radical leaves (11:10) growing from the very short stem on the short thick rootstock. The many inconspicuous flowers are borne in a spike (40:3) on a long flower-stalk. It is interesting as having the whitish, hairy sticky tip of the floret ripe before the pollen boxes. The pollen-boxes are expanded in a circle from the bottom to the top of the flower spike. Children call them soldiers, and often knock the tall flower-heads over. A gentle touch on a sunny spring morning may liberate the pollen, *i.e.*, cause the plant to "smoke."

The introduced catchfly (66:7) is becoming a common weed of the wayside and pastures throughout town and country. The outside of the cup is very sticky (68:6) and is said to catch small insects. The plant belongs to the carnation family, and the white and pink flowers are conspicuous.

The Wandering Jew (*Tradescantia*) is the commonest plant of schoolrooms (66:8). It grows freely in water, and is generally called the "water plant." The pretty, whitish flowers, with many white hairs, which are said to be eaten by certain flower-visiting insects, are not well known. The plant grows freely in a neglected, shaded corner of the garden. The leaf base (12:19) ensheathes the weak stem, which often trails down prettily.

The cranesbill and storksbill are members of the Geranium family (66:9). The seed-box and long "beak" often bear a striking resemblance to a bird's (crane's or stork's) head and beak. The five seeds are scattered by twisting off the plant, and they are planted (4:8) in the ground by the long

Plate 67.—SOME PLANT FOES.

tail. This coils and uncoils in dry and wet weather. The end becoming fixed in vegetation, the seed is driven further in with each movement. Sometimes the seeds have done harm to domestic animals. Children are fond of placing a seed on a sleeve and watching the end turn. They sometimes call them "clocks." Another species throws the seed out of the sling (47 : 17).

L.—SOME PLANT FOES.

St. John's Wort, *Hypericum perforatum* (67 : 1) is the weed that attracts most notice in Victoria at present. It is a serious pest in the north-east, where acres have been rendered worthless by this obstinate pest. The roots may go four feet down, and the many stalks of the perennial plant grow up to four feet in height in Victoria. The small unstalked leaves show many clear dots when held to the light. The clusters of flowers are very bright yellow. The petals have black dots along the edge. The plant is a native of Europe, Asia, and America.

Anyone finding a specimen outside the infected area should report the matter to the Agricultural Department.

Ragwort (67 : 2) in the southern dairying districts has almost taken possession of certain lands. The name is probably due to the ragged, much-dissected leaves. It is a perennial with bright-yellow flowers, and it seeds freely, so that it is troublesome in pastures.

There is confusion in name between the onion weed and the onion grass. The onion weed is a lily, *Asphodelus fistulosus* (67 : 3), a native of Southern Europe, while the "onion grass" (67 : 6) is a member of the *Iris* family. There is some confusion concerning the correct name of the onion grass. It was generally called *Romulea bulbocodium*, introduced from South Africa, and therefore called the Cape Tulip. The sticky tip of this species projects past the pollen boxes. Professor Ewart has shown that it is *Romulea cruciata*, a native with sticky tip not projecting past the pollen boxes. The reason for the sudden and alarming spread of this troublesome pest of the roadside is said to be the driving back of cockatoos. These birds formerly dug up the corms (67 : 6) and fed largely on them. Now that the cockatoos, a slight pest at certain seasons only, have departed, the permanent pest flourishes practically un-

checked. The shot-like seeds are thrown many feet by the sudden straightening of the elastic, wiry fruit-stalks (67:6) displaced by wandering animals.

The sheep sorrel (67:4), a member of the dock family, is a serious pest in some cultivated land. Careless cultivation breaks up and spreads the underground root-stocks, from each part of which plants can grow. The spear-shaped leaves containing oxalic acid are unsuitable for fodder. Acres are colored reddish by this introduced pest.

The small stinging nettle (67:5) must be classed as a weed. The stinging hairs (13:8) suggest flasks of formic acid. The slightest touch suffices to break the delicate wall of silica of the stinging hair, which forces the irritating acid into the wound. If gripped firmly, the hairs are bent down or crushed. The nettle follows man and occupies his waste places and rubbish heaps. The male (5^{11}) and female (5^{1}) flowers are borne in groups.

Capeweed (67:7) is considered by some a weed. Cape dandelion is another common name. It is an aggressive plant, developing with the first autumn rains, growing quickly, spreading out flat in a very big rosette on the ground, and choking out more valuable plants. The simple leaves, with many gaps out of the edge, allow light to pass to the two or more layers beneath. If, however, capeweed plants are crowded, they grow upwards, and the leaves are vertical; the woolly backs of many showing white in a breeze. The flowers are flower-heads showing division of labor. The outer so-called "petals" are really strap florets devoid of the essential parts of the flower; they advertise. The disc florets are complete flowers, with the four series of parts. For a small expenditure of material, many seeds can be produced. They stand on a hollowed cushion fully exposed to sun and wind. Many yellow patches dot the black center of the flower. The yellow is the pollen from some florets on the brush-like head of the seed-box. As few florets ripen their pollen at the same time, the bees pay many visits to each flower. The five pollen boxes are arranged in a ring as in the dandelion; the pollen is shed inwards and lifted up by the sticky tip. The sticky tip proper is the slight slit at the top. The two parts do not curl back as in the dandelion; self-pollination is impossible. The green bracts

on the back of the flower-head open and close the flower at night, and when the sun is hidden by clouds.

When cross-pollination is complete, the flower-head closes and bends down (67:7) out of the way until the seeds are perfected. The cushion becomes convex, thus spreading out in a ball the light, woolly seeds, which are now held erect and are blown away readily, leaving a series of little pits (67:7) on the top of the rounded end of the flower-stalk.

The capeweed completes its life-history and year's work early and dies off, leaving bare patches from which other plants have been crowded. In some dry districts, it is considered a good fodder plant. In others, when long, dry grass is abundant, it is considered a good plant to mix with that grass. In winter, it is often avoided by cattle; it has too much water about it, and large clumps are left in the paddock. Compare lady's mantle (187:27; 16:9). Children make chains of the flowers.

The bidgee-widgee, *Acaena Sanguisorbae* (67:8; 47:4), a cousin of the sheep burr (47:3), is a native plant well known to picnickers about Christmas time. The burrs with the barbed hooks catch in the clothing and the seed heads are carried away. They readily break up and cause much trouble to the wearer, who wishes to get rid of the unsightly burrs. Usually she does not appreciate the work she is doing for the plant in scattering the seeds far and wide. The burrs have perfect barbs or hooks. The plant is a member of the rose family and is related to rose, cherry, and apple.

The common centaury (67:9), a member of the Gentian family, grows in pastures and fields. It has opposite leaves without leaf-stalks, and bears a group of pink flowers. The plant is very bitter and is often used medicinally.

M.—Plants that Catch Animals.

Animals, from the point of view of food, are parasitic on plants; all our food, fuel, and clothing, are ultimately derived from green plants. It is therefore interesting to find that occasionally the tables are turned, and that there are plants that derive part at least of their nourishment from animals. In addition, there are some others that hold or imprison animals, though not feeding on them.

The most famous of the carnivorous plants is perhaps the pitcher plant, *Nepenthes* (68:1), where a part of the leaf

is modified into a vessel with a lid. The lip of this vessel is lined with down-directed processes, so that an insect once in cannot crawl out. The vessel is partly filled with a digestive liquid: insects are soon digested.

The Venus fly-trap (68: 5) is described in most textbooks. Kerner noted that when one of the spines was touched, the two leaf-like structures closed in from ten to thirty seconds.

PLATE 68.—SOME PLANTS THAT CATCH ANIMALS.

The French catchfly, *Silene gallica* (68:6) is said to catch small insects on the sticky cup, which serves possibly to prevent the stealing of pollen by creeping insects.

Pisonia, the last one mentioned, has been connected with seed scattering, and introduces an interesting partnership between birds and trees. As noddy terns fly in and out of these fine shady trees on the coral islets the fruits adhere to

PLATE 69.—SOME GALLS.

They can crush soft bodies, and the glands secrete an acid which can digest any insect caught.

The small bladder wort, *Utricularia* (68: 2) has bladders with the entrance guarded by processes that prevent the escape of small forms such as water fleas. A plant in an aquarium at the Botanic Laboratories, Melbourne University, held prisoner several mosquito larvæ of the genus *Culex;* each was held by the breathing tube and the end of the abdomen, and was far too large to be ingested.

The commonest of the carnivorous plants are the sundews of the genus *Drosera* (68: 3). In England, two species inhabit marshy regions. In Victoria, ten species, inhabiting ordinary hillsides and grass lands, are found. The glandular hairs close on a fly and imprison it in the cup-like leaf. The indigestible residue is worked outwards and dropped. If a plant is dug up, it will be found to have a food store that enabled it to get an early start in the spring. A second store is being prepared for next year.

The teasel (68: 8), which has an ant-trap formed by the growing together of the opposite leaves, has a stem arising from this water cavity; this probably suggested the ant-traps used about cupboard legs. Professor Miall says that flies and other insects caught in these traps are digested.

Some plants catch animals in connexion with pollination. The cuckoo-pint, an Arum (68: 4) is the best known of these. The offensive odor of putrefaction attracts certain insects, which climb down the central axis. The hairs in the narrow part now prevent their return until the pollen is ready to be carried to another plant. A second set of hairs separates the male flowers from the female flowers.

The lower set relaxes first, and the insects climb up to the male flowers, get covered with pollen, and then escape to another flower.

A specimen of a plant that was catching butterflies was sent from Warrnambool to the Botanic Laboratories, Melbourne University, by Mr. McKenzie, nature study teacher of the high school there. It proved to be a milkweed, *Asclepias*, introduced from South America. Insects accustomed to the flowers carry the pollen masses on their feet to another plant, but in a strange land some get caught by the proboscis (69: 9) and cannot extricate themselves.

shape of these scale galls is various, torpedo (8) and acorn galls (10, 12) are figured. The hole at the summit denotes the female scale gall. Insects of many families are concerned in the formation of galls.

Witches' brooms (69: 4) are a form of gall; some are said to be due to a fungus, and others to the attacks of small insects called thrips (123: 9).

Hard brown knobs (69: 15) occur on some trees, especially kangaroo acacias and native cherries (*Exocarpus*). These are caused by a fungus allied to the rust of wheat.

The gall is of no use to the plant, but it is of great use to the plant's enemy. Why the plant should form the structure for its enemy is not clear.

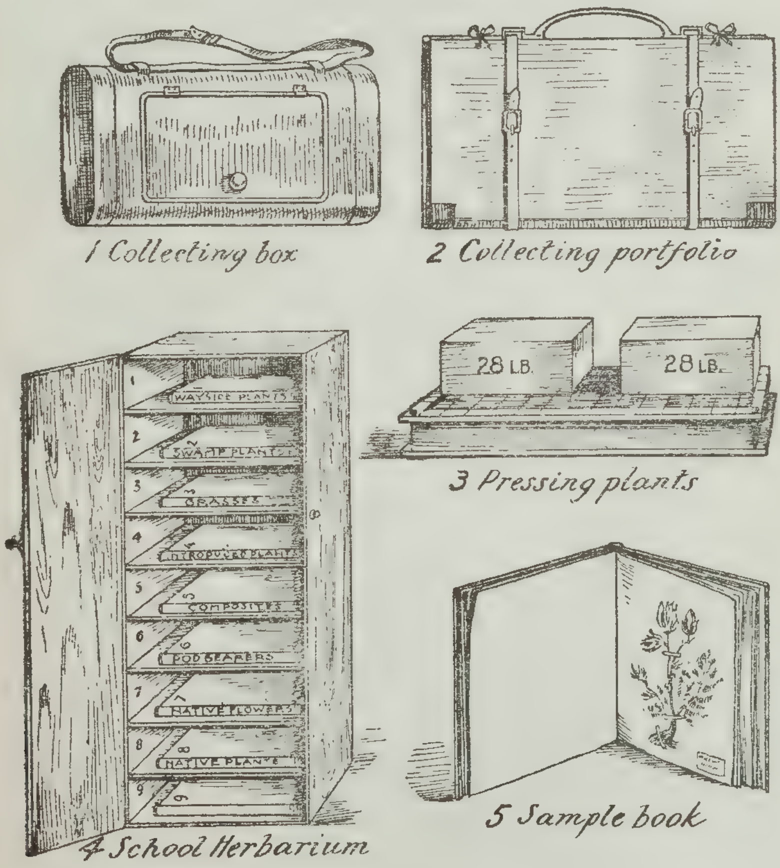


PLATE 70.—COLLECTING, PRESERVING AND MOUNTING PLANTS.

them, and possibly drop off on a sandbank or small island. Occasionally so many fruits adhere that the birds cannot fly, and perish. Possibly the presence of birds' bones under this tree gave rise to the legend of the deadly Upas tree, the tree of death. It was said to be certain death to sleep under its attractive shade. We enjoyed the shade of giant *Pisonia* trees on the islands of the Barrier Reef.

N.—GALLS.

Galls (69: 1-15) are puzzling plant structures. Any part of a plant may bear them, and one plant may bear many different kinds of galls. Just how that plant differentiates between the different stimuli and responds exactly to it, growing each time the one form of gall for the particular parasite, is not easily understood. Plants can respond to stimuli even more exactly than animals do. A few of the more common galls are mentioned here to introduce to the young student an interesting field for study and research.

Small rounded swellings on eucalypt leaves (69: 1) will be found to be occupied each by the larva of an insect. Larger galls of this kind are often called apple galls (69: 3). Many are bright red in color and suggest small fruits. A big swollen caterpillar-like mass (69: 2) along the edge of a leaf proves to be inhabited by several small larvæ that develop later into small two-winged flies (*Cecidomyia*). Many leaves of eucalypts are a beautiful purple color and have a felted mass (69: 4) on the leaf. These structures, felt-galls, are due to a mite, an animal with four pairs of legs (128: 3, 5, 6). Any part of a plant can become changed into a gall—leaves, stems, buds, flowers or roots. Some wattle trees bear no blossom; all the flower buds are transformed into galls, serving as the homes of many larvæ.

Amongst the most remarkable of galls are those due to scale insects (*Brachyscelis*) (69: 8-12). These contain a big wingless female (69: 9) with six tiny legs, sucking mouth-parts, and narrow, elongate abdomen. The male, a minute insect with only two wings, emerges from small tube-galls as shown on the side (69: 11). The winged gall, with long, green, leaf-like structures on it is also a *Brachyscelis*. Scale insects, it is said, do not form galls in other countries. Figure 12 shows galls on a gall, one set of small gall-insects developing in the wall of an acorn gall (*Brachyscelis*). The

PART II.

ANIMAL LIFE.

CHAPTER XVI.

THE LOWER INVERTEBRATES.

Animals and plants together are treated in the science of biology (*bios,* life), which includes all living things as distinct from lifeless things, *e.g.*, rocks, water, and clouds.

Plants have already been studied; they are treated in the science of botany; animals in the science of zoology.

The animal kingdom is divided into several large groups or phyla, of which back-boned animals constitute one phylum, and animals without bones, the remaining phyla.

A.—Animals and Plants.

Most people consider they can distinguish an animal from a plant. How? Animals move and plants are fixed. But sponges and corals are fixed, and Volvox and many other plants move about. Try again. Animals eat solid food and plants take liquid or gaseous food. Tapeworms are animals that take only liquid food, while sundews (68:3) eat flies, and so take solid food. Plants have flowers and animals have not, but the lower plants have no flowers. Plants have leaf green and make food, and animals do not. Mushrooms and other fungi have no green and do not make their own food, and yet are undoubtedly plants, while green Hydra and some other animals contain the green that manufactures food. Plants have cellulose and animals have not. The tunicates or sea-squirts (137:5), however, have a tunic of cellulose, a typical plant substance. It is easy to distinguish a plant high up in the scale like a cabbage from an animal high up in the scale like a horse; but, as the simpler forms are reached, it is impossible to divide plants from animals. "There are no hard and fast lines in nature." Both have descended from a common ancestor. Strasburger, in "*A Text-book of Botany,*" calls *Volvox* a plant, and Parker and Haswell in "*A Text-book of Zoology,*" an animal.

0.—Plant Collections.

Collecting, Preserving, and Mounting Plants.—Unless a collection can be properly maintained and kept in order, it is better that no collection should be formed. A good collection properly kept is a great aid to knowledge.

It is essential that plant specimens be properly dried. To that end they should be pressed as soon as picked or kept fresh until they can be pressed. A withered plant will not make a good specimen in a collection. When collecting, carry a small portfolio (70: 2) with sheets of blotting paper or newspaper. Place the specimen flat between two sheets and strap tightly. Or carry an air-tight collecting box (70: 1) to hold the specimens until they can be placed in the press. On reaching home, transfer the plants to a press of blotting paper (70: 3). Change the plants to fresh paper daily and spread out the used sheets to dry. The object of pressing is to remove all trace of moisture. The Melbourne Herbarium has plants collected by Robert Brown, who accompanied Flinders on his voyage over one hundred years ago, as well as some plants collected nearly 200 years ago. If well pressed and dried, the plants will, with proper care, last indefinitely. Therefore, press thoroughly, and use dried paper daily. The next necessity is to enter data: name, name of collector, name of locality, date, and notes.

The next important matter is to keep out museum pests. This is extremely difficult. Carbon bisulphide in an air-tight compartment will in time kill every pest. Naphthalene is another good preventive, but frequent examination of specimens is necessary, for a plant or animal collection will not look after itself. A neglected collection is soon worse than none.

For a school herbarium, Mr. H. B. Williamson, F.L.S., a leading field botanist, recommends a series of volumes of royal grey paper similar to that of the grocer's sugar bag. The specimen is fastened to the sheet (70: 5) with slips of gummed paper, the necessary data is written on neatly, and the plants of different kinds in the school locality are grouped together according to the desires of the student. Each book is kept on its proper shelf (70: 4) in the school herbarium.

C.—Sponges.

The well-known bath sponge is really the skeleton of an animal (71 : 1-6), that, during adult life, is fixed to the one spot. A current of water flows in through many small pores and out through larger ones (71 : 4). The living cells take in food and air from this water. The scientific name, *Porifera,* for the group, refers to these pores. The supporting skeleton is sometimes horny fibres (bath sponge), or limy (calcareous) spicules (Latin *spiculum,* a dart) (71 : 6), or siliceous (glassy) spicules of various shapes. Some sponges are very beautifully colored, others are delicately formed. Neptune's fingers (71 : 1) and goblet (71 : 2) are two common forms. The free-swimming young spread the race to new places.

Australian sponges should be as valuable commercially as those of the Mediterranean Sea and Florida.

D.—Hollow-bodied Animals (Coelenterata).

Jelly-fish, sea-anemones (sea-flowers), and related animals have stinging cells which often affect a human being seriously. These animals are sometimes grouped as "stinging animals." They have no blood or stomach distinct from a body cavity. Hydra (72:1; 187:7), found in ponds the world round, is a hollow sac; the outer layer of cells is concerned with meeting and knowing the outer world, and the inner layer with digestion. Hydra is a two-layered animal, and has no body cavity other than the digestive cavity. Hydra and related animals are called hollow-bodied animals (Cœlenterata). They make up the third group of the invertebrates. Tentacles richly armed with stinging cells get food into the mouth. The food is digested and the indigestible part is egested. When full grown, buds appear on the side ($72: 1^1$), gradually mature, and pinch off from the adult. Eggs are also produced. If Hydra is turned inside out, it still lives, changing the functions of the cells. Occasionally it travels along, looping like a leech on the under side of the water surface. The stinging cells shoot out a thread which numbs the prey. A green Hydra colored by "the green" of green plants is not uncommon. A few animals possessing the green can manufacture starch.

Obelia ($72: 2, 2^{i}, 2^{ii}$) is a fixed hydra-like form (hydroid, *oidos*—form). It is a colony. Some polyps (individuals) do

Still, for our purpose, animals are easily separated as food consumers, while green plants are food producers.

B.—One-celled Animals.

The simplest and smallest animals, consisting of one cell, form the first group of one-celled animals, Protozoa. As these are mostly microscopic forms, there is little place for them in the class nature-study of children up to eleven years of age. Though too small for general nature-study, they are important in the economy of nature and on the earth.

The chalk of the "white cliffs" of Dover is mainly composed of the minute "shells" of one-celled animals. Large nummulites (166:6) suggesting coins are common fossils in the limestone of which the pyramids of Egypt are built.

Volvox is often claimed as an animal, and as filling the gap between one-celled animals (Protozoa) and the many-celled animals (Metazoa).

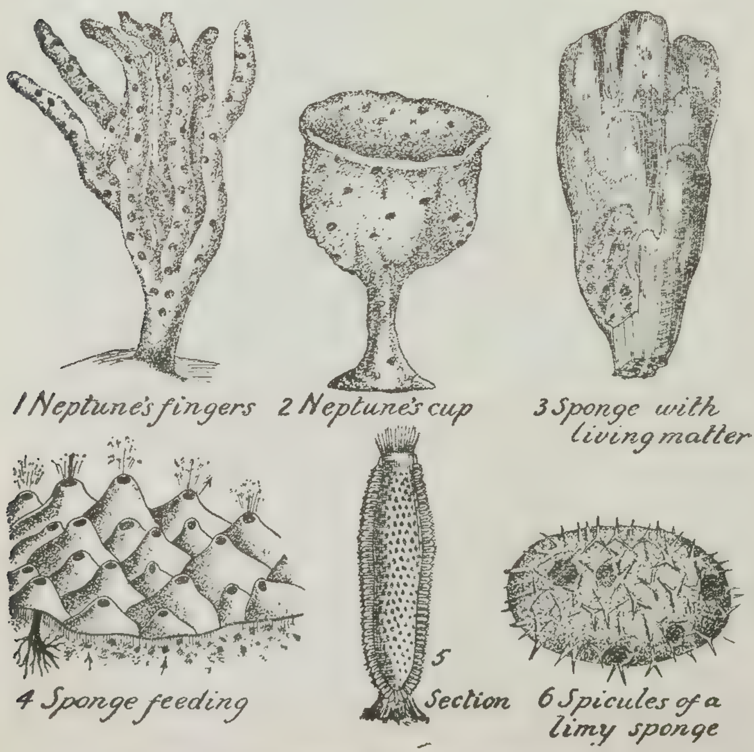


Plate 71.—SOME SPONGE STUDIES.

the feeding, some bud off tiny jelly-fish (2^{11}) which produce eggs; there is division of labor between these feeding and reproducing individuals. The jelly-fish, swimming away to new places, produces eggs which become the fixed Obelia. There is an alternation of generations, a fixed form—bud-

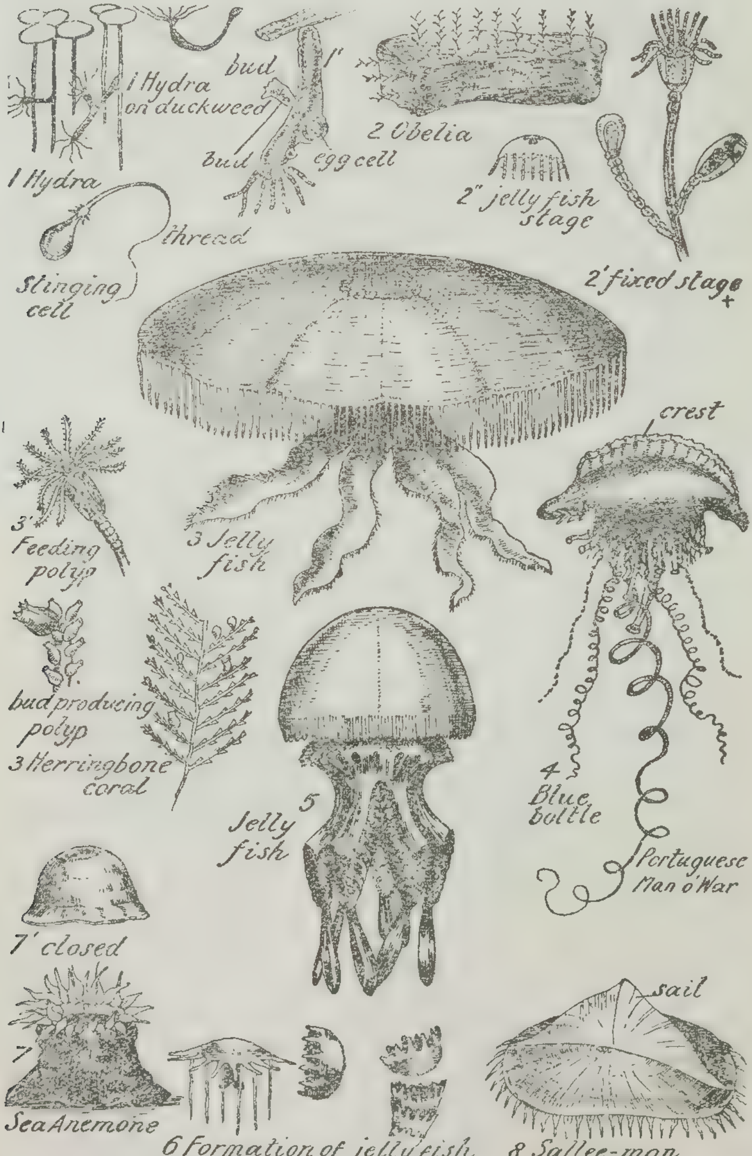


PLATE 72.—STINGING ANIMALS OR HOLLOW-BODIED ANIMALS.

ding and a swimming form—reproducing by eggs. The bracken fern and aphis show this interesting phenomenon.

The "herring-bone coral" (72: 3, 3¹) is often called the "sea-fern"; it is common on the beach. The branches suggest tiny fretwork saws. A feeding polyp lives in each little cup; larger polyps produce buds growing into jelly-fish.

Large rounded jelly-fish (72: 5) of many forms and sizes are bloodless and have the mouth between the frilled arms beneath the center. Some are a considerable size and all are armed with stinging cells (72: 1), which may cause intense suffering. The animal progresses by contracting and expanding the hemispherical swimming bell. The cross in the top of the back is the mass of egg-producing cells. The eggs of some kinds develop into a fixed form (72: 6), which pinches off many free-swimming jelly-fish.

The beautiful dark "blue-bottle" or Portuguese man-o'-war, *Physalia* (72: 4) shows much division of labor. There are feeding polyps, stinging (protective) polyps, egg-producing polyps, and a large swimming (floating) polyp. Surf bathers have been kept off the beach at Manly by numbers of these stinging animals. The beach near Cape Howe was inches deep in dead blue-bottles in November, 1914.

The Sallee-man, *Vellela* (72: 8), is sometimes found on the beach here. The floating polyp with an oblique "sail" attends to locomotion, others serve for feeding, defence, and egg-production as in the blue-bottle.

Sea-anemones or sea-flowers (72: 7, 7¹) abound everywhere about a rocky beach; they are retracted as a colored jelly-like mass when the tide is out, and expanded like a flower when the tide is in. Some disguise themselves in sand and shell fragments. They are first cousins of true corals, but have no skeleton. They can shuffle along a little on the sucker. The prey is numbed by the stinging cells.

Corals (73: 1-9) are common as curios in many homes in Australia. This is natural when we reflect that Australia is the great head-quarters of corals. The Great Barrier Reef, 1100 miles of coral, built by the tiny coral polyps, causes many of man's great structures to sink into insignificance. In the days to come, this reef and its hundreds of products will be of immense importance to Australia.

The true corals have plain feelers arranged in groups of six. A second group of corals has eight fringed feelers. These include three figured here.—(1) The red coral of commerce (73: 1, 1¹) is used for brooches and ornaments; instead of being formed of plates, the skeleton is really formed of spicules matted together. (2) The red organ-pipe coral (73: 2, 2¹), with green polyps, is another coral made up of spicules. (3) The seapens (73: 3), of many forms, have a stiff rod supporting the polyps with fringed tentacles. The mushroom coral (73: 4) is a true coral allied to the sea-anemone, but with numerous radiating plates. The young are fixed on a stalk, and have a cup at the top. Soon this "turns inside out" by growing down at the edges. The stalk is lost and the single polyp lies free.

The true reef-building corals (73: 5, 6, 8, 9), flourishing in warm, clear, shallow water, have numerous polyps each living and supported by plates, often in a little cup. As the coral reaches low tide level it grows outwards.

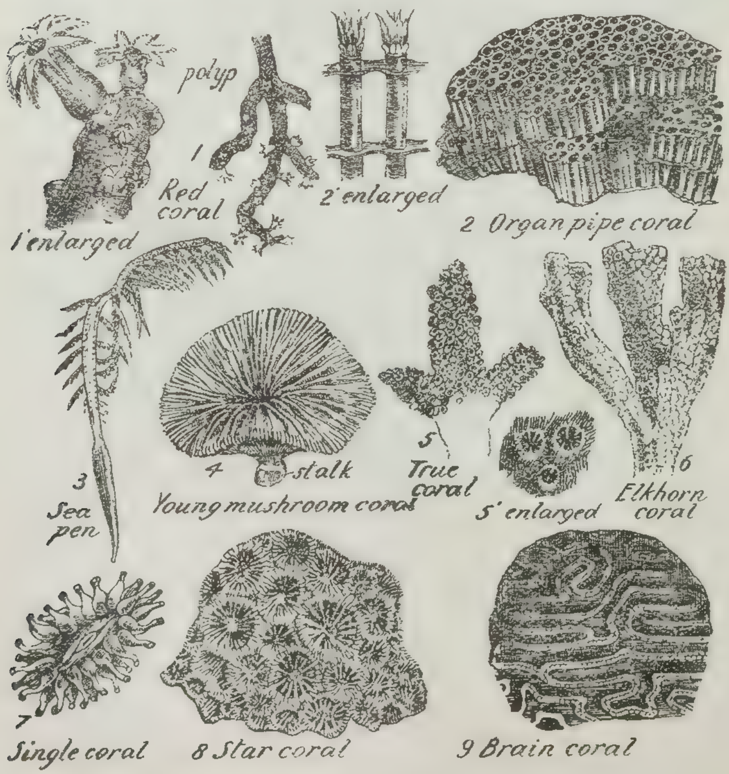


PLATE 73.—SOME CORAL STUDIES.

Star corals (73: 8), which have no cup except that formed by the meeting of the plates of different polyps, are common. A star coral lives in Port Phillip Bay, but seldom exceeds the size of the palm of the hand. The water is too cold.

The remarkable brain corals (73: 9) show lines where the plates meet; these suggest the convolutions of the brain.

Corals do not flourish in deep, cold, or muddy water; hence there is usually a passage in the reef opposite each river. They flourish best on the outside, where the moving waters bear plenty of food and air.

A warm current down the east coast of Australia, and a warm current down the west coast to Steep Point and Houtman's Abrolhos Island, bring more than half the coast-line of Australia within the coral area. On account of the cold currents, corals do not flourish along the western shore of South America.

A coral reef itself is a great coral cemetery, consisting of blocks of coral broken off by storms and tossed up by the waves. It is formed from a quarter of a mile to two or three miles from the enclosed island. The shallow lagoon between is really the wonderland. When the tide ebbed (it fell 16 feet on the Barrier Reef), the lagoon at Mast Head Island was seldom more than 2 or 3 feet deep. The time until the tide turned again was always too short to exhaust the wonders and beauties of the small area examined. A series of flat coral "trees" or tables grew from a central stem up to the level of the lowest tide, and then spread out quite flat on the top. Many were from four to six feet across, and amongst the branches many beautiful animals sheltered. In places one could walk for 100 feet or more on these "tables." Corals of many kinds and colors abounded.

Giant clam shells (134: 5), with beautiful velvet fringes, closed when touched, and squirted a jet of water several feet high. Expanded sea-anemones (72: 7) of many sizes, forms, and colors were feeding. Remarkable sea-worms (75: 1-7) with delicate tufts of breathing "hairs" withdrew into tubes. Crabs, shrimps, and sponges were present in endless variety. Fish of many shapes and colors darted away when disturbed. Sea-urchins (136: 6, 8), star-fish (136: 1-3) and sea-cucumbers (136: 11) and trepang all claimed notice. Coral eels, suggesting sea-snakes, snapped

snail (132: 3, 4) within a very short time or it dies. It burrows into the lung of the pond snail and there passes through two stages (3^{ii}, 3^{iii}). Leaving the pond snail as a tadpole-like form (3^{iv}), microscopic in size, it swims about until it settles down on a piece of grass. It can stay there for a lengthened period until eaten by a sheep, then it passes along the bile duct to the liver. Burning the rough grass round crabholes destroys many pond snails and many of the waiting forms. Ducks and water-frequenting birds such as herons and magpie-larks do great good, but many more are wanted to keep this pest down. It is doubtful if it pays to shoot wild ducks, which destroy many pond snails. A form of fluke infecting human beings has been introduced from Egypt by Australian soldiers. This fluke passes through its intermediate stages in a pond snail, and, swimming freely, may settle on human beings who are bathing. The worm stage of some tapeworms is large, and they are troublesome parasites. In others the bladder stage is large and the worm stage small. The hydatid is one of these. The small worm is harmless to a dog; but, in the bladder stage the animal is troublesome to man and rabbit.

The land planarian (74: 5), or slime worm, is a flat worm. It has no blood; the stomach branches throughout the animal, so that each part can receive food direct. The mouth, with a protrusible throat, opens about the middle of the body on the under side. A bulldog ant has little chance with a land planarian, for the slime soon obstructs the feelers and the ant is uncomfortable. Found under logs and in damp places, these soft-bodied worms are of many colors.

The *EARTHWORM* should be considered as an important soil-preparer, a burrower, a leveller, and an active agent in preparing the earth for plants and animals. It is well adapted to its lowly life of burrowing through the ground. Cylindrical in shape, it suggests the boring tube of a diamond drill. It, however, has no hard boring structure, it softens the soil and swallows it. The earth swallowed as the animal burrows is ground up and well mixed in the muscular gizzard. The earthworm is mainly a vegetarian. Darwin showed that it had preferences, and would find a dainty morsel hidden in the soil. Though it has no definite sense-organs, it can smell and taste. It is sensitive to vibrations,

viciously at a stick or a net. A ten days' camp left a determination for a further visit to this paradise of naturalists—no flies, no mosquitoes, no land pests; but a deep, shady forest free from undergrowth, to explore when the tide was in. As a health resort for jaded business men, the Barrier Reef will be valuable in the future.

E.—Worms.

Worms are now divided into several groups: flat-worms (fluke), round worms (thread worms), and ringed worms (earthworms and seaworms), are perhaps best known.

FLAT-WORMS include many important parasites: liver fluke (74: 3), tapeworm and hydatid, all live in two hosts. The liver fluke, resembling a tea-leaf, lives in the bile ducts of the liver, and causes "liver rot" amongst sheep and, rarely, human beings. The adult becomes a bag of eggs (150,000 or more), and passes to the outside. The young (74: 3) swims actively in ponds and must meet a pond

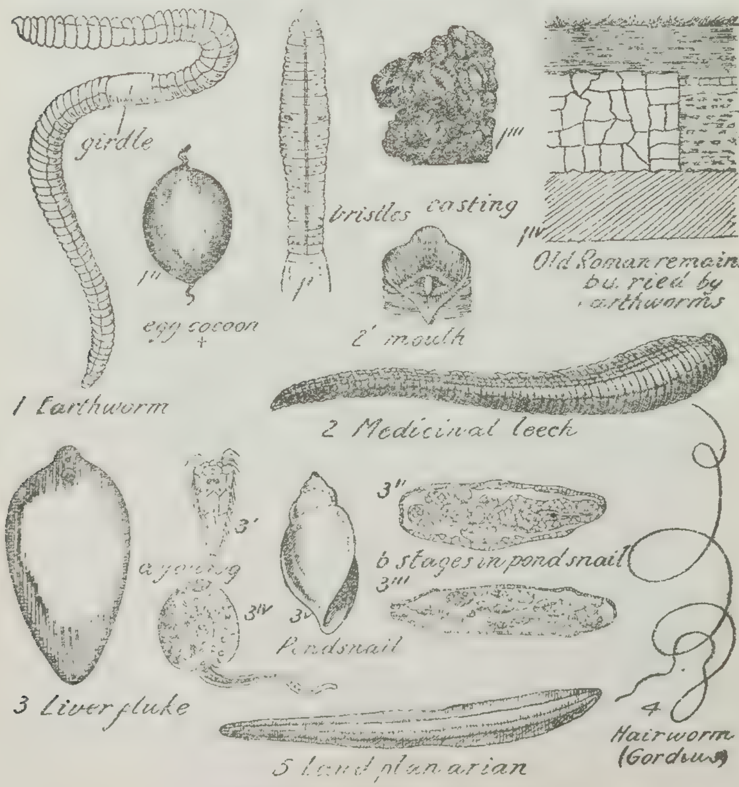


PLATE 74.—WORM STUDIES.

and has a delicate sense of touch. It has no projections to interfere with its passage underground, and is moist and slippery. This moisture serves to oil the burrow and to moisten the skin, which is the breathing organ. Oxygen passes into the blood and the carbon dioxide passes out.

Pull a worm from a burrow. Pull gently or it will break in two. How does it hold? Each ring of the common earthworm is provided with four pairs of bristles. These are protruded by special muscles into the sides of the burrow. It also crawls with the aid of these bristles. It protrudes those at the hinder end, fixing that part of the body. The front part is thrust forward, the front bristles are protruded, and the hinder end drawn up. When forcing itself through loose soil, it behaves similarly. Rub a finger over the bristles.

Put two or three worms in water for a time. See the big blood-vessel along the top of the back. The blood is red, not like ours, colorless, with red blood corpuscles. The red coloring matter is here in the blood itself.

About one-third of the distance back is a smooth "girdle" or "saddle." This secretes a cylinder of slime (mucus). The worm then draws itself backwards through this, laying the eggs in the cylinder as it does so. The ends of the cylinder close together forming the "egg-cocoon." Generally only one egg develops in each cocoon. The young finds plenty of food in the cocoon, and emerges as a small worm.

The earthworm is a simple animal divided into as many compartments as there are rings. The common earthworm has about 150 rings. Our big South Gippsland worm, which may be 7 feet long and as thick as a man's thumb, has several hundreds. The worm shows hardly any specialization. If it be cut in two, each half grows the missing portion. Occasionally you will come across a worm with the new portion very small—just beginning to grow.

Keep some earthworms (179: 5) in a vessel with soil. Put some dead leaves on the surface. See what becomes of them.

Collect some castings from amongst the grass. Darwin showed that, in England, they averaged ten tons per acre per year. Our climate is too dry to get the full benefit from these humble helpers. The castings have buried ruins.

The remarkable *HAIR-WORM* (74: 4), parasitic in one stage in water-beetles, sometimes issues from water-taps in

Melbourne. It is usually tied in a kind of "Gordian knot," hence the name *Gordius*.

The *MEDICINAL LEECH* (74:2), with five pairs of simple eyes is a common animal in some water-holes. There is a constant demand from the hospitals for the five-striped leeches to suck blood from wounds. The Melbourne Hospital is paying 5s. per hundred for an unlimited number of thousands of the five-striped variety. The black leech is not suitable for the purpose. The medicinal leech has a mouth with three sharp-toothed jaws, that soon cut through the flesh. The animal then fills its crop with blood, which its saliva prevents from coagulating. The one meal may suffice for several months.

Using the mouth and the large sucker on the posterior end, the leech loops along quickly; it swims actively with graceful undulations of the body.

Small land leeches, with two jaws, are sometimes troublesome in swampy or scrubby country.

Earthworms belong to the group *Oligochaeta* (*oligos*, few; *chaeta*, hair), with few hairs, though some Australian

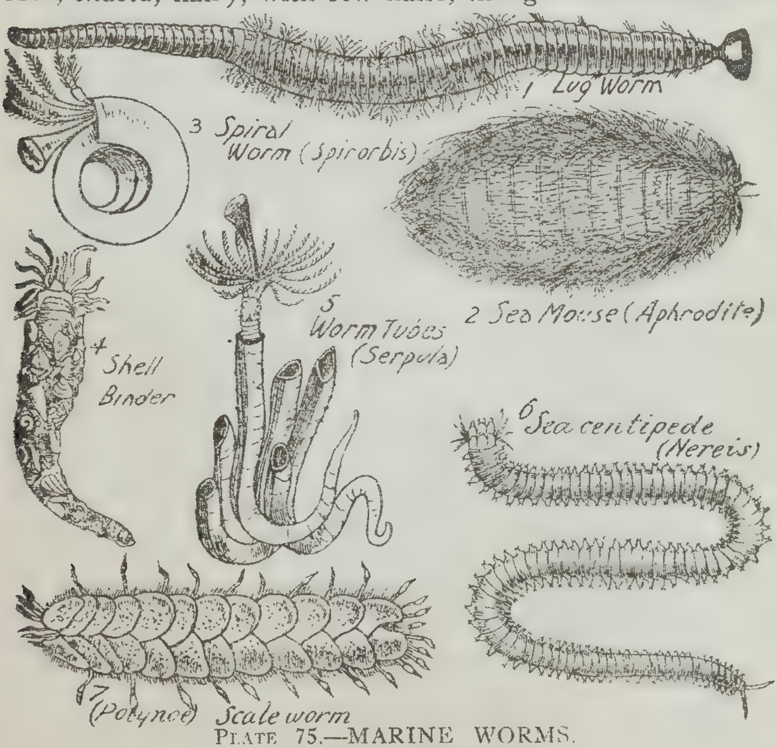


PLATE 75.—MARINE WORMS.
3, Much Enlarged.

forms, instead of four pairs, have hairs almost round each ring. Seaworms form the group *Polychaeta* (*poly,* many), the members of which have many hairs. These are often iridescent and of great beauty.

The story runs that a Greek philosopher named his seven daughters after his favorite worms, but, as the worms had already been named after nymphs and goddesses, the daughters did not suffer much. Some of these worms live in tubes, some are free.

The sandy castings of long lug-worms (75 : 1) from their burrows on a damp beach may often be seen. These worms form a favorite bait for fishing. In clear water they are beautiful animals, with tufts of hairs.

The "sea-centipede," *Nereis* (75 : 6), has a definite head with feelers, jaws and eyes. It has no jointed legs, but projecting bristles suggest legs. Some of these worms are two feet in length. They are not air-breathers related to centipedes, but are water-breathing marine worms.

Nereis occasionally buds off a young one in a peculiar way. The hinder part of the body forms a constriction and develops a head and eyes. Before separating, a second and even a third young one develops in the same way. If broken in two or three, each part may develop fully.

The "scale-worm" (75 : 7) is a form with overlapping plates or scales; it is met occasionally when studying beach life or when dredging. The sea-mouse, *Aphrodite*, is oval in outline, and covered with beautiful hairs. It is one of the most beautiful of the group. The tube-living sedentary forms are various and beautiful. The shell-binder (75 : 4) cements rough shell fragments together. The long breathing processes about the head are beautiful. One kind makes a perfect tapering tube of sand grains cemented evenly and firmly together. Serpula (75 : 5) forms a mass of limy tubes often seen thickly encrusting a rock in water. The lime is obtained from sea-water by the animal. Small spiral worm tubes are often seen. The worms that live in these have breathing hairs and a stopper for the tube.

F.—MOSS ANIMALS AND LAMP SHELLS.

Moss animals (*Bryozoa* or *Polyzoa*) often build masses suggesting coral reefs. Such once lived in Spitzbergen. These hard structures are of many forms, from the so-

The Golden Bower-Bird

called "curly seaweed" and "corkscrew seaweed" to the red "seamat" (76: 6) and "lace coral" (76: 5). The fresh-water Plumatella is common in permanent ponds. The polyps are more advanced in structure than coral polyps.

Lamp-shells (76: 2), with shells above and below, are distinguished from ordinary bivalves like mussels and cockles, which have a shell on each side of the body. Lamp-shells are extremely ancient forms of life. *Lingula,* the goose-bill lamp-shell (76: 4), seemingly perfectly adapted to life in mud, has no reason to change, for its conditions have not changed. It still survives, though it is known in the oldest series of fossiliferous rocks (Cambrian).

The common lamp-shell (76: 1, 2) has the lower valve large and produced into a beak with a hole in it. A stalk anchors the animal to a rock or other body. The illustration shows several young Port Phillip Bay lamp-shells on an oyster shell. The animal feeds and breathes by making with a fringe of tentacles arranged on a delicate limy loop (76: 3) a current of water. The shells cannot be opened wide without breaking something. They resemble an ancient lamp, hence the name.

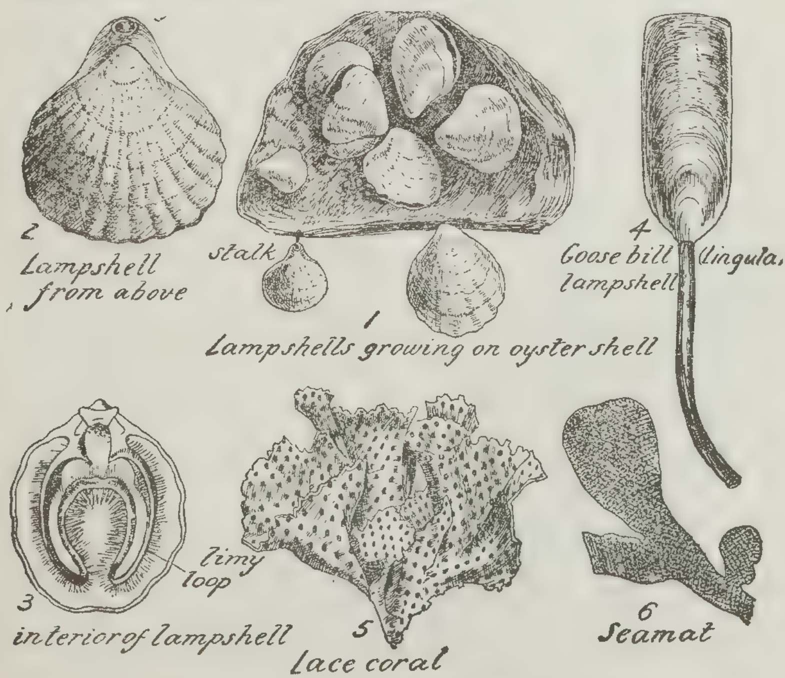


PLATE 76.—LAMP SHELLS AND POLYZOA.

CHAPTER XVII.

JOINTED-LEGGED ANIMALS—ARTHROPODA

Joint-legged animals represented by crayfish, Peripatus, centipedes, insects and spiders, and embracing more than half the known animals, are of great interest to nature-students; they make up the large group (phylum) of Jointed-legged Animals—Arthropoda (*arthros,* jointed).

A.—The Freshwater Crayfish and its Allies.

There is a considerable crayfish industry in Europe, but the freshwater crayfish is not much used for food in Australia. The freshwater crayfish (77: 1) lives in running or standing fresh water, and even in temporary swamps, where a heap of earth around a hole about an inch in diameter often indicates a crayfish's home.

The misleading name crayfish is probably a corruption of the French *écrevisse.* "Yabbie" is a native name.

Carnivorous from choice, sometimes eating their mates, crayfish also eat roots. The body has a hard crust or shell, which forms a shield over the head and chest. The main parts are two—head-chest and tail. There are many segments, each typically bearing two limbs. The tail has six hard, convex rings and a tail-piece. The small first ring of the Australian crayfish is limbless; the second, third, fourth and fifth segments bear Y-shaped "swimmerets"; the sixth limbs, placed alongside the tailpiece, form a powerful swimming fin, used when darting backwards.

The head-chest has many segments, each bearing two limbs. By counting the limbs, we can number the segments. The short double feelers (77: 2) are first; the long whip-like feelers bearing a small plate are second. Every crayfish has three pairs of jaws. These five pairs of appendages denote five segments in the head.

Starting from the hind part of the chest, there are four pairs of walking legs, the big seizing claws, and three pairs of foot-jaws, legs that help to get food to the mouth. The chest thus has eight pairs of limbs, denoting eight segments. The crayfish consists of head-chest and tail, comprising nine-

teen (5+8+6) rings and the tail-piece. The crayfish shows a series of wonderful adaptations, the limbs being modified for different functions: swimming, egg-carrying, feeling, hearing and smelling, getting food, crushing food, seizing enemies or food, walking and fighting.

The provision for movement in the armor is perfect. The tail bends, driving the animal backwards. At the flexible joint between two hard rings, two pegs fit into sockets in the adjoining ring, allowing perfect up-and-down movement, but no side movement; in the big claw several perfect hinges allow movements in all directions. The animal is well provided with sensory structures. The first double feelers serve for touch, smell, and hearing. On the inner branch are

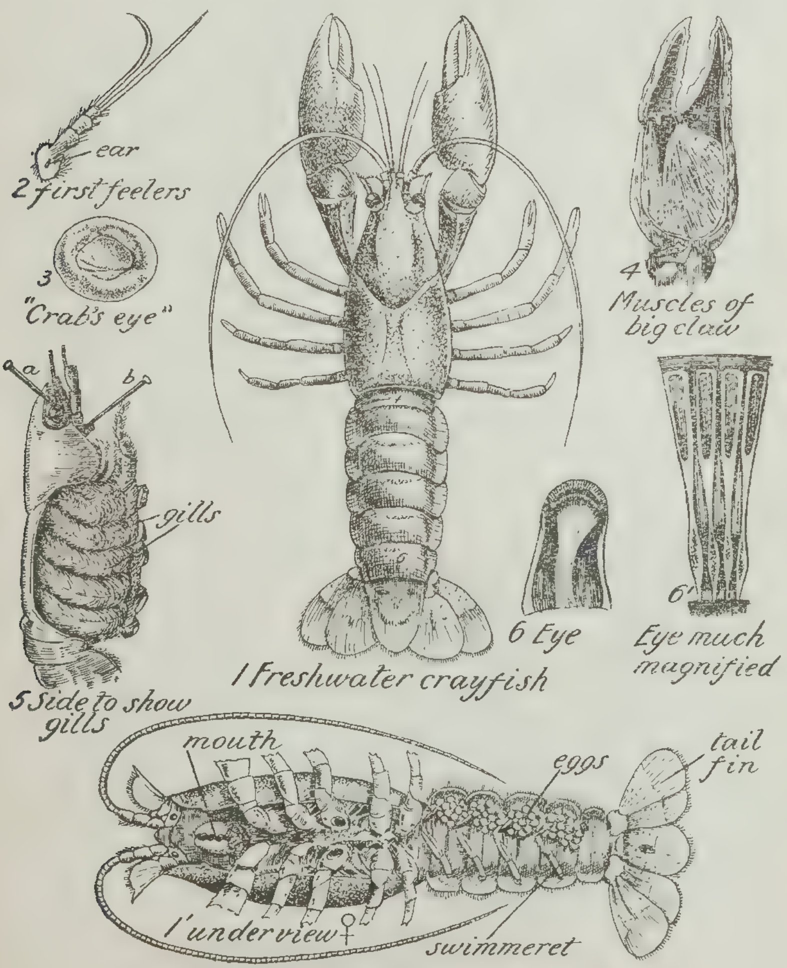


PLATE 77.—THE FRESHWATER CRAYFISH.

flattened smelling hairs, on the base (77 : 2) is the so-called "ear"—a pit containing sensory hairs and grains of sand, suggesting the grains (otoliths) in our ears. In related animals, the "ear" is always in this position, or on the tail-fin (Opossum-shrimp).

The movable compound eyes have many facets (77 ; 6, 6^1). The shield, fitting the head closely, is attached to the chest at the top, partly enclosing the gill-chambers (77 : 5). Along each side, near the top, is a groove, marking the edge of the body proper. If you cut a moulted skin outside this groove and place it in water you will see the gills, resembling bottle-brushes. To supply oxygen, water runs through the gill-chamber. Near the head groove, the shield swells a little, forming a hollow in which the boomerang-shaped "baler" causes a current of water from behind. Show this in two ways. Hold a living crayfish out of water; bubbles appear near the groove. Dip a tube into dilute red ink, place a finger over it; place the end carefully at the back of the shield; remove the finger; soon a colored stream issues.

Two parts especially are eaten, the white flesh, the muscles from the tail and legs. Lean meat is muscle. The legs are hollow-jointed tubes. Each joint has two muscles (77 : 4); one bends it, the other straightens it. Break open the sixth joint of the big claw. See the tendon that fastened the muscle to the end-piece, having a "peg and socket joint."

At the base of the big feeler, see a small hole, the opening of the kidney (green gland), strangely placed in the head. The color of crayfishes varies; some are pretty, though often a brownish-grey predominates. Some parts are occasionally a beautiful blue, with a red connecting skin. Crayfish are red when cooked. There is said to be a living red crayfish. Many live crabs are red.

On the sides of the chamber into which the mouth opens are two circular white "crab-eyes" (77 : 3) of unknown use; they were once popular as medicine, and are often found in dry swamps or river backwaters. Crayfish cannot grow; they must moult the non-elastic armor. The completeness of the moult is marvellous. Each limb is drawn back from its seven-jointed skeleton, and a perfect model remains. The soft animal then grows rapidly, and a new armor forms. Moulting, so Thomson says, is the "dis-

advantage of the advantage of armature," it often kills the weak. Crayfish possibly moult from two to eight times during the first year. Even after crayfish reach full size, they moult occasionally, getting rid of parasites living on the shell. Crayfish are pugnacious. Should one be caught by a limb, it may escape by shedding that limb. A fresh limb grows, each moult adding to its size.

Crayfish show maternal care. The eggs (100-200) are attached to the mother's swimmerets ($77: 1^1$); the young hang there by the big claw.

The presence of crayfish in a new dam is sometimes thought mysterious. While the gills are moist, the animal can live out of water. In wet weather, it may wander far. Burrowing in irrigation channels, crayfish are an expensive nuisance, letting much water escape. The blue (white-fronted) heron deals effectively with them.

The big-clawed lobster of Europe is much bigger than the spiny Murray River "lobster." The marine crayfish, often sold as lobsters, have no big biting claws, though the corresponding limbs act as effective weapons of offence. The other structures are generally similar to those of the fresh-water crayfish. Shrimps (78: 7) and prawns (78: 8) are also long-tailed decapods (crustaceans with 10 legs). The shrimp has the big claws on the first legs as in the crayfish. The prawn has the big claws on the second legs.

The mantis shrimp (78: 9) has a mantis-like seizing leg resembling the well-known fly-trap of Mantis and other animals. The opossum shrimp (*Mysis*) has the "ear" on the tail-fin. The hermit crab ($78: 3, 3^1$), a long-tailed decapod, is really not a crab. The soft tail is protected by a mollusc's shell in which it lives. As it grows, it finds a larger shell. The structures that form tail-fins in crayfish here form a hook for hooking on to the shell.

Crabs (78: 1, 2, 4, 5) are animals of most varied form and color to meet different conditions. Up to a certain stage, it is impossible to distinguish a young crayfish from a young crab. Then the crab, more adapted for walking, develops the head-chest at the expense of the tail, which becomes very small and is carried tucked into a groove (78: 2).

Structure for structure, the crab matches the crayfish; the feelers are short; the eyes usually well developed, are often

on long stalks and can be folded up or down. The shield is much expanded sideways, and encloses the gills, permitting considerable time away from water. The male can be distinguished from the broad-tailed female by the narrow tail (78:6). The female carries the eggs under the tail.

The big claw is sometimes extremely well developed, but more often is not unduly developed; the walking legs are usually formed for burrowing. Some crabs run sideways,

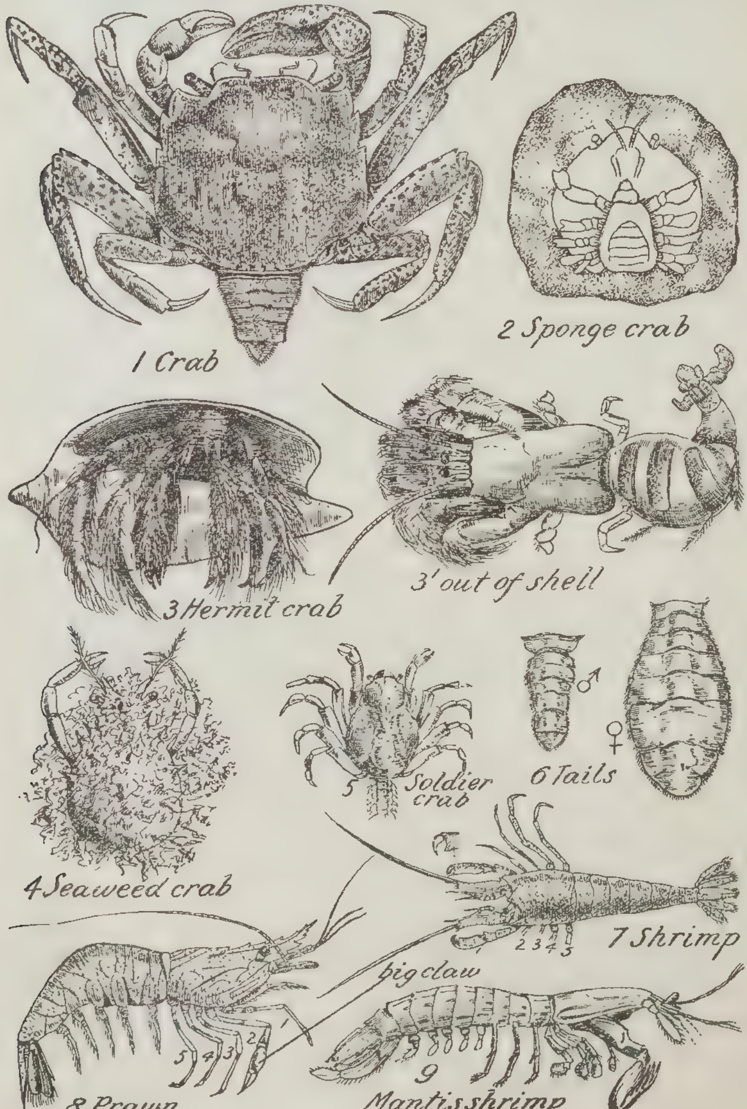


PLATE 78.—CRABS, PRAWNS, AND SHRIMPS.

some backwards, and some forwards. A swimming crab has the last chest-leg flattened as a swimming paddle.

Crabs live under all sorts of conditions. One is parasitic inside the sea-mussel. One lives in partnership with a sponge (78: 2). This effectually hides it, while the sponge is carried to new places for fresh food and water. Another crab dresses in seaweed (78: 4), hooking it on to processes on its shield. If changed from a patch of red seaweed to a patch of brown, it will change its coat of seaweed.

Soldier crabs (78: 5), in countless battalions, plough up a tidal flat at low water. As an observer advances, they burrow and disappear.

The common crab in Port Phillip Bay is the British shore crab, supposed to have been introduced on a ship's bottom in the days of the gold rush of the fifties.

In temporary pools the scale-tail or "toe-biter" *Lepidurus* (79: 6), is at times common. Its fearsome look frightens young people. It is an ally of the larger, well-known Apus (79: 5, 5^{1}), and the textbook description of that animal applies closely, except that Lepidurus has a scale between the tail-spines. The shield, responsible for the name "shield-shrimp," is fastened only in front. It bears two large eyes. Sometimes a long horse-shoe marking shows the shell-gland, possibly the equivalent of the kidney. The scale-tail has 63 pairs of leaf-like limbs (79: 5), which serve for breathing as well as for locomotion.

The eggs are carried in circular brood-pouches on the 11th flattened chest-legs (79: 6^{1}) on each side. The eggs withstand desiccation for lengthy periods and blow about in the dust. They may, in wet seasons, develop in unexpected places. Temporary shallow, weedy, swampy pools are the usual home of this harmless animal. Floating moulted skins are a good indication of its presence. It is difficult to keep it alive in an artificial aquarium.

In Central Australia, where pools soon dry, such animals often develop with extreme rapidity. Those that develop rapidly to the egg-stage persist; the others die out.

The almost transparent fairy shrimp (79: 12) is a somewhat similar animal, but it has no shield; it appears occasionally in great numbers, and may not be seen again for years. The male has peculiar claspers on the head.

Estheria (79:7) and Cypris (79:8) remind one of bivalves; they have a shell on each side; if touched, the shells close and the animal sinks. The jointed limbs show that these animals are not molluscs, though the shells certainly resemble bivalve shells. Some of these may be three-quarters of an inch long. A common Cypris here is small; hence the common name "full-stop."

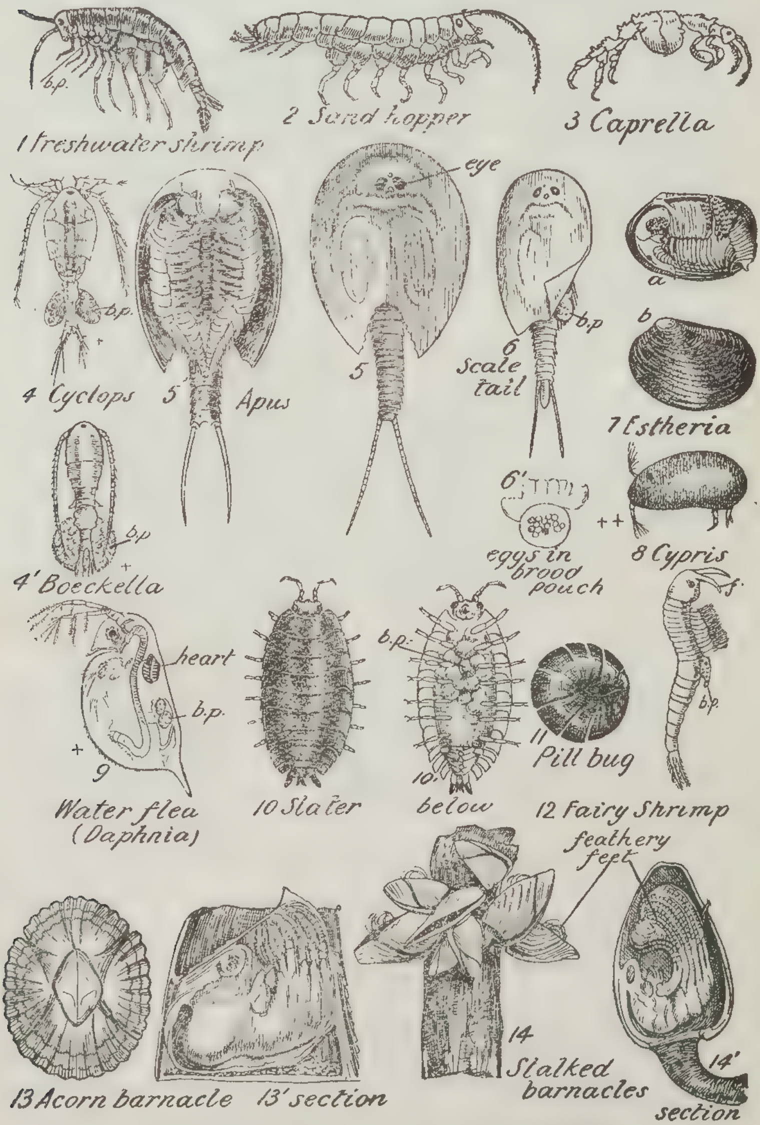


PLATE 79.—SOME CRUSTACEANS.
1, 2, Enlarged. 4, 4[1], 7, 8, 9, Much enlarged.

Daphnia (79:9), the "water-flea," is enclosed between two flattened, rigid shells, grown solid about the head. The large-branched feelers are the chief swimming organs. Daphnia "swims with its feelers and breathes with its feet." The curved alimentary canal can be seen, also the facets of the compound eye, and the heart beating in the back. The young may be seen in the brood pouch. One (for in favorable conditions males are unknown) Daphnia "in nineteen days produced five broods, totalling 209 individuals, which became mature in ten days, and were able to reproduce in like manner. These produced broods of fifteen every three days; so that, if all lived, there would be 12,000,000 individuals in less than two months." If these creatures were left unchecked, the earth would soon become a solid mass of them. Fish and even whales derive much of their food, at least indirectly, from such small forms, which, in turn, feed on plants. When times are bad (cold or drought), males appear, and two resting (89:17) or "winter-eggs" (in England cold is the bad condition) are to be seen. These may withstand desiccation for years, and may be blown far.

The one-eyed Cyclops (79:4; 89:18; 187:17) is another of these tiny pond-dwellers. Like Daphnia, it swims with its feelers. The eggs are carried in two egg-sacs. A larger related form, Boeckella ($79:4^1$), has one egg-sac.

In the same group come the fixed barnacles (79:13, 14). The free-swimming larva, resembling that of Daphnia and Cyclops, indicated the relationship. The barnacle larva swims freely; by and by it takes to the fixed habit, stands on its head, cements itself to a suitable object, and degenerates. A barnacle has been described as an animal that "stands on its head and kicks its food into its mouth with its feet." Stalked barnacles ($79:14, 14^1$) float and travel far. They are often found attached to a piece of wood washed up on the beach. The six pairs of feathery legs may sometimes be seen. The body is enclosed by five plates. These barnacles were formerly thought to change into geese. One goose is still called the barnacle goose.

The usually small acorn barnacle (79:13) is fixed. It lives on rocks or shells. The five plates close into a hollow in the top of the enclosing cylinder. Great numbers of very small acorn barnacles live exposed on rocks between tide levels.

The small freshwater shrimp (79: 1; 189: 13), Gammarus, is the typical form; the Australian form is called *Chiltonia,* after Chilton, a New Zealand authority. Its body is flattened from side to side. It is related to the sand-hoppers (79: 2) abundant on the beach under masses of dry seaweed; the latter is practically a land dweller.

The strange, slow Caprella (79: 3) is sometimes seen crawling over seaweed. It carries its eggs in a brood sac, and is difficult to see amongst the seaweeds.

The slater (79: 10, 10^1), called also piggy, or sow-bug, or wood-bug, is flattened from above downwards, and has small black jaws opening sideways. Most crustaceans are water-dwellers, but the slater is a permanent land-dweller, breathing moist air by means of the plates on the tail. Some plates appear white because of air in them. The compound eyes are flat on the head. The seven pairs of legs are all similar (equal), giving the name *Isopoda* (equal legs) to the group. What their food is is disputed. Some say slaters eat dead food and are beneficial; others say they destroy seedlings.

The slater shows much maternal care, and carries possibly fifteen young in the brood pouch under the chest.

A related form rolls into a ball (79: 11), suggesting the American name, "pill-bug." In America, the name bug is used for any small animal, especially an insect; in Australia the name bug is used for sucking-beak insects (121-123).

The crayfish and its allies are crustaceans; the name is due to the hard crust or covering.

B.—Peripatus.

Peripatus (80: 6), the "most primitive existing Arthropod," is a rare, caterpillar-like form, living under logs. Like insects and centipedes, it breathes by tracheal tubes. The nervous system suggests that of flat worms and shell-fish, the excretory system resembles that of earthworms, so that Peripatus is a connecting link of extreme importance to zoologists. Its remarkable distribution—Australia, New Zealand, Malay Peninsula, South Africa, Central and South America, and the West Indies—denotes extreme antiquity and the presence of land bridges where such are absent now.

C.—The Many-legged Animals.

The many-legged animals, comprising centipedes, shield-bearers, and millipedes, make up the class *Myriapoda* (Gr. *murioi,* ten thousand).

CENTIPEDES (80: 1) are poisonous; only experienced students should collect specimens. Centipede means 100 legs. One kind has 15 pairs; the common kind, 21 pairs; and another, up to 173 pairs of legs.

The head bears feelers and four pairs of small glistening simple eyes, which are probably poor for sight. Beneath the head is the mouth, with jaws resembling insect jaws. The front limbs form strong poison-jaws (80: 1^{i}), giving a painful bite that causes swelling and suffering. Each of the 21 similar segments, plated above and below, bears two five-jointed clawed legs (1^{ii}), with bases far apart. The last legs are harmless "bluffing trailers."

Centipedes are carnivorous and, apart from the bite, are beneficial. Being nocturnal, they hide in a convenient recess by day. Seeing them in hollows in plants, some think them injurious to plants.

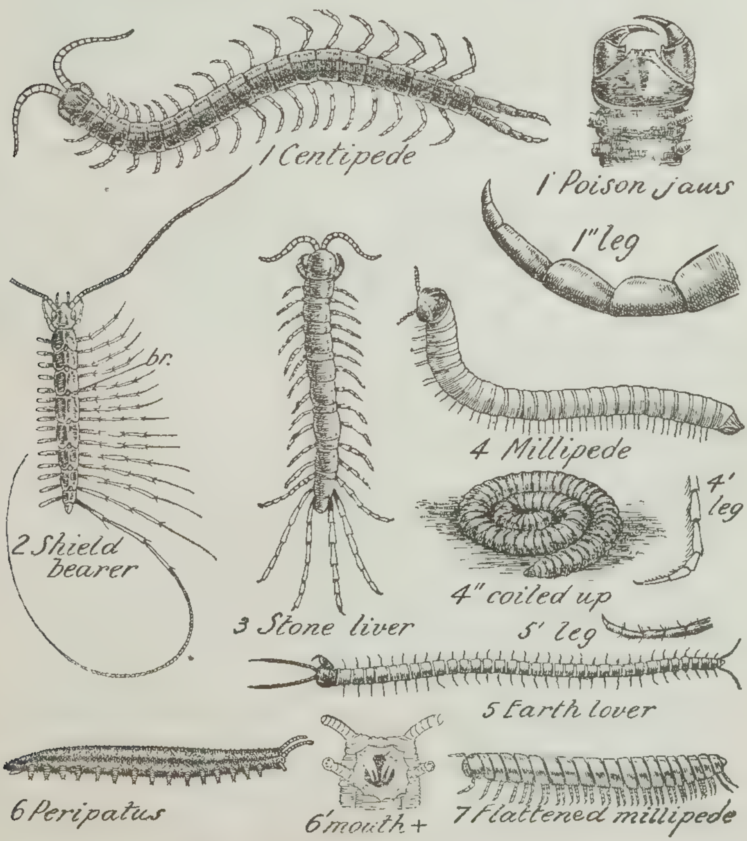


PLATE 80.—PERIPATUS AND MANY-LEGGED ANIMALS.
1-5, Many-legged Animals; 6, Peripatus.

Dr. Ray Lankester has quoted the following stanza on the complicated way the legs move:—

" A centipede was happy quite
  Until a toad in fun
Said, 'Pray which leg moves after which?'
This raised her doubts to such a pitch
She fell exhausted in the ditch,
Not knowing how to run."

The breathing holes in the ordinary Australian centipede are on segments:—3, 5, 7, 8, 10, 12, 14, 16, 18, 20.

Centipedes may coil about their thirty or so golden eggs. The cold-blooded mother is not keeping them warm, but protecting them from enemies; young resemble the old.

Centipedes flourish in most countries. They occasionally issue from water-taps in Melbourne. The largest authentic record of size known to the writer is about seven inches.

The *STONE-LIVER, Lithobius* (*lithos,* a stone; *bios,* life) has a shorter body (80: 3) of fifteen rings and longer legs associated with quick movement; the female is said to hide the eggs from the greedy male by rolling them in dust.

EARTH-LOVERS, Geophilus (*ge,* earth; *philos,* love), have no eyes and are narrow and comparatively long; generally, each alternate smaller ring is legless. The short legs vary from thirty-five to 170 pairs or more. The harmless animal (80: 5) has a serpentine movement, and often lives underground or under bark. Stone-livers and earth-lovers are still common close to Melbourne.

Harmless, worm-like *MILLIPEDES* (80: 4) are often called "wire-worms." Three animals are called "wire-worms": the larva of the click-beetle (106: 7), the larva of the crane-fly, leather-jackets (117: 4[1]), and the millipedes.

Millipedes may have 200 body segments and about 800 legs; each segment, except the three, four, or five nearest the head, bearing four short jointed legs. The slow millipedes, coiling into a spiral, may produce an obnoxious fluid from "stink glands" on the back. Some are about the diameter of a two-inch wire nail. They are found in gardens, or under logs.

The vegetarian millipede has no poison jaws; its jaws are true jaws, not foot-jaws. Hence the name for the order means jaw-jawed: *Chilognatha* (*cheilos,* a jaw; *gnathos,* a

jaw) as opposed to foot-jawed centipedes—*Chilopoda* (*cheilos,* a jaw; *pous,* a foot). One, the "banana worm," is as large and thick as a Fiji banana.

Millipedes lay from sixty to seventy eggs. When born, the somewhat flattened millipede has three pairs of legs, suggesting a connexion with insects. At each moult it gets more segments and legs, until attaining the adult rounded form. A flattened adult millipede (80:7) is much rarer than the round-backed forms.

The "*SHIELD-BEARER*" (80:2), running rapidly, seems all legs; hence the name, "thousand legs." The long, hair-like legs suggest "Johnny hairy-legs." When caught by the legs, it leaves its wriggling legs behind; hence it was named *Schizotarsia* (*schizo,* to cut off; *tarsus,* the ankle). It has fifteen segments with fifteen pairs of long legs, and is covered above by eight plates or shields; hence the name "Shield-bearer," *Scutigera* (*scutum,* shield; *gero,* I bear). The legs lengthen backwards until the last feeler-like legs are clawless, possibly serving as feelers.

The carnivorous, beneficial shield-bearer has comparatively simple poison jaws, and its bite, perhaps fatal to its prey, is harmless to us. The head bears feelers, jaws, poison-jaws, and faceted eyes—compound eyes resembling insect eyes. The breathing system is peculiar. The seven breathing holes are in mid-line at the indentation in the hinder edge of the seven shields. Each leads to a "lung" of much-branched breathing tubes, suggesting the spider's "lung-book." The breathing tubes are actually in the "heart," which runs along the animal's back.

D.—INSECTS (SIX-FOOTED ANIMALS).

Insects swarming in most countries are possibly the most widely-spread and abundant of all animals. Possibly one-half of the known kinds of animals are insects. Built on a simple plan, yet modified for life under most diverse conditions, insects are of great economic importance, and also of much interest to nature-students.

An insect is so named because it is made up of, or "cut into," three parts which, however, are not always distinct. Further, some animals not insects have three main parts.

Insects are best recognized by the six legs, thus the name *Hexapoda* (six-footed) is often used for the class. Larval

ticks, mites, and millipedes have six legs, but the adults have more; they are not insects. Insects have one pair of feelers, while crayfish have two and spiders none.

THE COCKROACH (81: 1-11), a large common insect of house and field, is much studied as a type by science and nature students. It has six legs, two feelers and the usual three parts—head, chest, and body. The head is bent under, and may be covered by the fore-chest; when

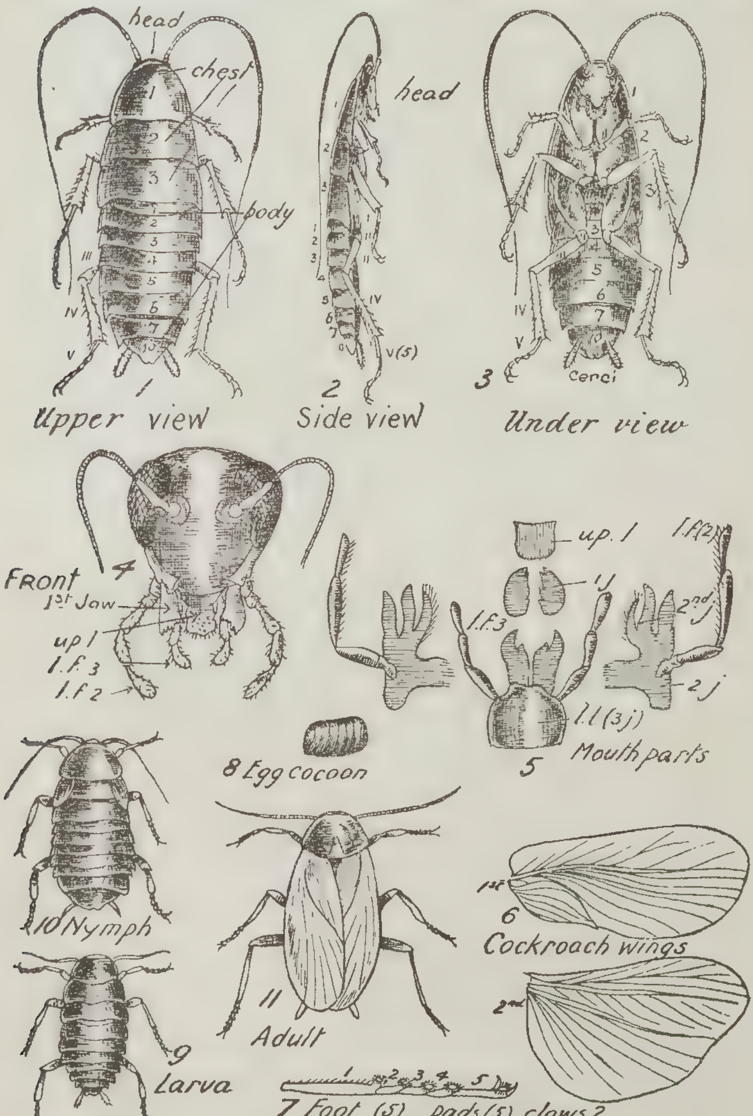


PLATE 81.—THE COCKROACH.

viewed from below (81:3), it has a peculiar goat-like expression. The compound eyes are large, though they have a limited range of vision. The long feelers, moving freely on ball and socket joints, constantly vibrate as the animal runs rapidly. The mouth parts (81:5) serve for biting and chewing. The strong biting jaws open sideways, as do the jaws of most invertebrates. The thin second pair of jaws help to keep food in the mouth. The third pair fused together forms the lower lip (chin). Over the biting jaws is the upper lip; the second and third jaws bear lip-feelers.

The chest is concerned with locomotion—flying and running. Each of the three rings bears a pair of similar spiny legs (85:1; 81:3); the first of the five parts is large; the last part, the foot (81:7), has five joints, each bearing a pad, the last joint has also two hooks. The animal can run up walls. How insects hold on is disputed. Air pressure apparently does not assist the cockroach. Possibly some fluid is exuded, but further investigation is necessary. Both mid-chest and hind-chest bear two wings, which distinguish cockroaches from beetles. A beetle's front wings (106:5) are stiff, enamelled shields, meeting in mid-line, and fitting the body closely. The horny front wings of a cockroach overlap (81:11), and are untidy when compared with those of a beetle. The flying wings have straight veins (81:6), and part of the wings folds fanwise. Many species have the wings reduced or absent.

The body (abdomen) bears two tail-feelers, cerci (81:3), which are flat, or thin and feeler-like; their use is unknown. The body of a cockroach has ten segments, only eight are visible externally. The beetle's hard wing-covers hide the segments. The cockroach may also be recognized by the reflexed head. Cockroaches breathe through holes (spiracles) on the sides of chest and body.

Cockroaches take care of their eggs; the female may be seen carrying the small brown egg-cocoon (81:8), which is about twice as long as it is wide, and contains sixteen eggs. After a time, this is deposited in a safe place. The larvae (81:9) soon emerge; they have been described as "entertaining pets." Striking comical attitudes, they go through an elaborate toilet, somewhat as a kitten does. They resemble the parents, and there is a gradual change at each

of the five moults until the adult form is acquired; there is no resting pupal (81:10) stage. Little is known definitely of the time the cockroach takes to reach maturity.

One Australian cockroach resembles the slater (79:10), but may be recognized by the six legs. The slater has seven pairs. About 1000 species of cockroaches are known, mostly in warmer regions; they vary in size, shape and color. They live in cracks, under stones and logs, and are mostly nocturnal. Some say cockroaches are flat because of practice in squeezing away into narrow places; others say those that can squeeze into narrow spaces escape their enemies better, therefore the flat ones are favored in the struggle for existence, and the round-backed forms are eliminated.

The food of the non-domesticated species being probably dead animal matter, they are useful scavengers. In cold countries, cockroaches live in houses, and undoubtedly find man useful to them. Taking advantage of ships, some species have spread widely. In Victoria, the common house cockroaches are introduced forms from America and Europe. The Australian cockroach is spreading in the United States; each, freed from its natural enemies, may become a pest. Fossil remains of cockroaches have been found in ancient rocks of the coal (Carboniferous) period.

INSECT STRUCTURES.—The head varies much; it is broad (Cicada) (82:1; 122:1), elongate and narrow (weevils or elephant beetles) (82:2; 107:4, 5) or rounded (grasshopper) (82:4; 95:1). Sometimes a definite neck unites head and chest (housefly and Mantis) (82:3; 94:2).

The chest, too, varies in some respects, though it always contains three parts—fore-chest, mid-chest, and hind-chest. The fore-chest is large in the cockroach (82:5; 81:1), and may cover the head; elongate in the Mantis (94:2), and broad and wedge-shaped in the burrowing mole cricket (82:c1; 96:2). The mid-chest is large in the leaf insects, *Phasmids*[1] (82:c3; 94, 1). In dragon-flies (82:c2; 97:2[1]) the three segments project forward, bringing the feet near the mouth and forming a fly-trap. The fore-chest bears the front legs; the mid-chest, the second legs and front wings; the hind-chest, the hind legs and underwings.

[1]Family names end in *idae*. The ending *id* denotes a family. Phasmid denotes a member of the *Phasma* family.

The body (abdomen) is even more varied. The number of rings is ten in the dragon-fly (82: d1; 97: 1) and cockroach (82: 10; 81: 1), nine in moths and butterflies, seven

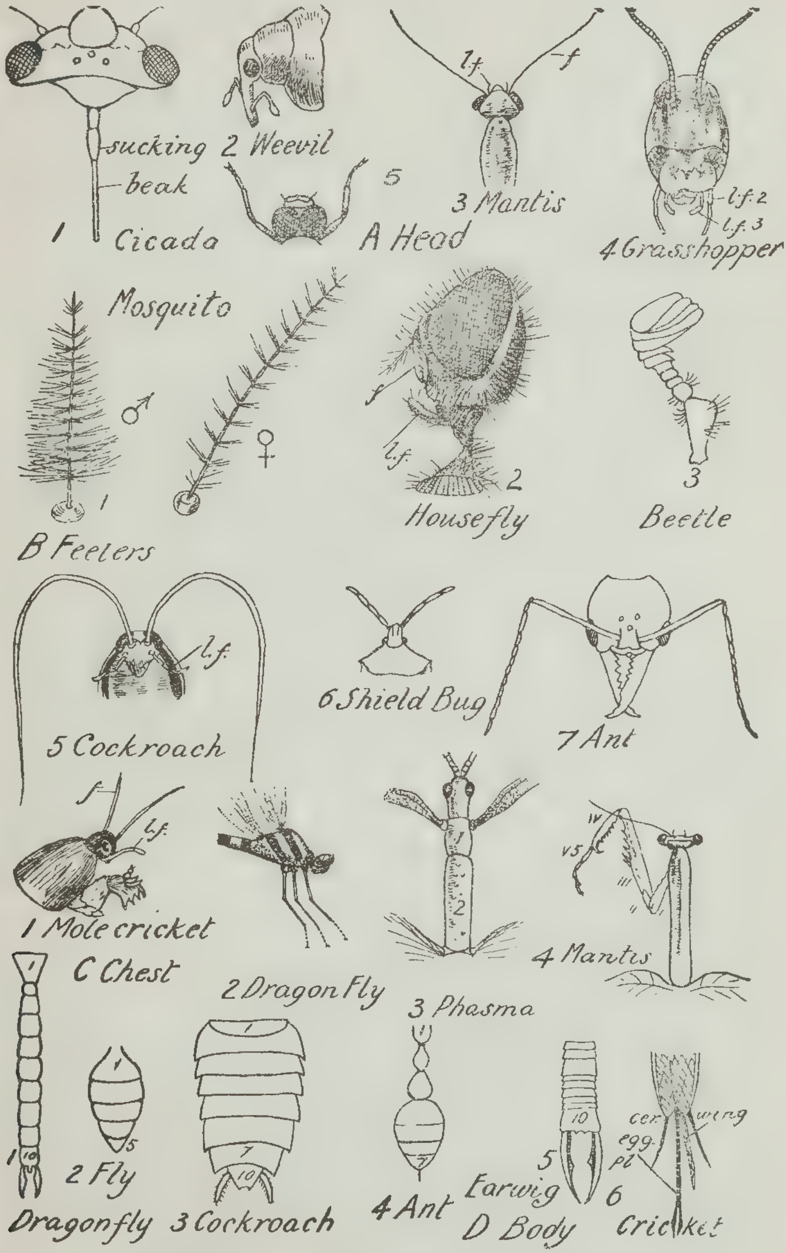


PLATE 82.—INSECT STRUCTURES—HEAD, CHEST, AND BODY
L.f., lip-feeler; cer., cercus (tail-feeler).

in ants, and five in the house-fly (82: d2; 117: 1). The abdomen bears no limbs. In the male dragon-fly it ends in two leaf-like structures; in cockroach and crickets, in tail-feelers (cerci). The earwig (82: d5; 92: 4) has two remarkable forceps. Female field crickets (82: d6; 96: 1^{iii}, 3) and others have a long egg-placer on the body. In worker bees and ants, this is modified into a sting. The water-scorpion, *Nepa* (121: 8), and others have a long breathing tube on the end of the body.

The head, concerned with sense organs and food-getting, bears appropriate organs for these functions. The feelers are interesting sense organs. Crustaceans, *e.g.*, crayfish (77: 1), have generally two pairs of feelers; insects have one pair. Possibly, the feelers serve for smelling and sometimes for hearing, as well as for touching. We have no feelers and cannot fully appreciate their use. Feelers vary in length—long in cockroach (81: 1; 82: 5) and katydid (95: 3), minute in the aërial dragon-fly (97: 1), which depends mainly on sight.

The form varies as in the comb-like feelers of the cockchafer (106: 5), the bristle feelers of the housefly (82: b2), and the hairy feelers of the mosquito (82: b1; 119). The feelers of worker ants have an elbow bend (82: b7; 102).

Waterbugs, backswimmers (121: 11), and others have "hidden feelers" folding into a groove, while "land bugs" (shield bug 82: 6; 121: 1) have "naked feelers." The click beetle (106: 7), simulating death, keeps the feelers closely pressed to the body. The feelers of butterflies are knobbed (108: 1, 5a); those of moths (108: 2, 5b) are usually hairy and pointed.

Insects and crustaceans have "compound eyes" made up of facets, each of which is surrounded by a dense pigment, which absorbs all light except that entering from the front. The number of facets varies. There are said to be 20,000 in the dragon-fly, 3000 in house-fly, and few in worker ants. The facets can be seen in the compound eye of Daphnia, the water-flea (79: 9). Each facet sees the point directly before it (83: 9; 77: 6^1), and the total image is a mosaic of small images. This type of eye is called a compound eye or "mosaic-image eye." In addition, many insects have simple eyes (*ocelli*) plainly seen in Cicada (83: 10; 122: 1). Spiders

(129: 1^{ii}) and leeches (83: 3) have simple eyes. Vertebrates have "inverted-image eyes" (83: 6). A lens inverts the image, which is received by the retina. Inversion also occurs in the pinhole eyes of chambered nautilus (83: 8) and

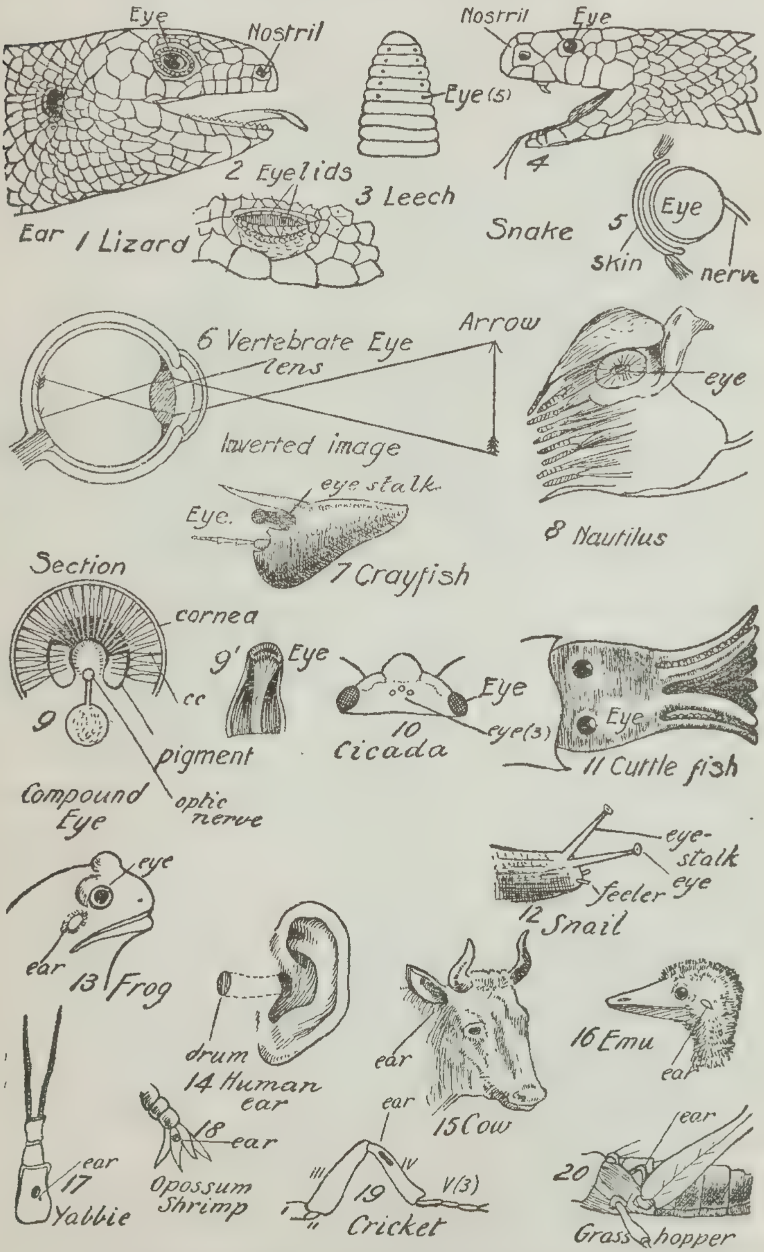


PLATE 83.—EYES AND EARS OF ANIMALS.

limpet (*Patella*), where a pinhole serves instead of a lens. A similar arrangement is seen in the long-exposure pin-hole camera, the lens being replaced by a card with a pin-hole in it. Insects cannot close the eye. The snake stares, for it has no eyelids (140: 3; 83: 4, 5); a lizard (83: 1, 2), having eyelids, can close the eyes. The open pupil in the center of our eye, revealing the dark pigment of the retina, is black. The iris, the colored curtain round it, regulates the amount of light admitted to the eye. In bright light, the pupil is small; in dull light, the curtain opens and the pupil is large. The crab (78: 1) and crayfish (83: 7; 77: 1, 6, 6^1) eyes are on stalks, and some fold down. The snail's eyes (83: 12; 132: 1, 1^{ii}), on hollow stalks, can be withdrawn easily. Cuttlefish (83: 11; 135: 3) have highly developed eyes with a lens, though not of the vertebrate type.

The ears of animals that have bones (vertebrates) are on the head; the ears of the invertebrates are variously placed; in crayfish (83: 17), on the small feelers; in cricket (83: 19; 96; 1^{iv}) on the front shin; in grasshoppers (95: 1; 83: 20), on the first body-ring; and, in the opossum shrimp (83: 18), on the tail-fin. In mammals, there is usually an external ear-conch. The cow's ears (83: 15) are behind the defensive weapons—the horns—otherwise they would suffer damage. The bird's ear-hole (83: 16) is visible only in naked-headed birds, *e.g.*, emu and turkey; the frog's ear-drum (83: 13) is on the surface. Lizards (83: 1; 140: 2) have an ear-hole, but snakes (83: 4; 140: 3) have no external ear. Associated with the vertebrate ear are the three semi-circular canals, the balancing organ of the delicate and important sixth sense concerned with maintaining equilibrium and balance. Children, when at play, sometimes set the fluid of the canals in motion and become giddy. Tossing up and down in a boat also sets the fluid in motion. Some people afterwards find that walking on land becomes uncertain. It is possible that the ear of invertebrates is balancing in function rather than auditory.

The mouth parts of insects are suited to various life habits and environments. Biting and chewing mouth parts (84: 1, 1^1; 81; 5) are probably most common. The mandibles (first pair of jaws) open sideways; they are effective masticating organs. Caterpillars, *e.g.*, silkworms, may be heard chewing their food. The second jaws are leaf-like

and perhaps assist in keeping food between the chewing jaws. The third pair of jaws grows into one structure, the lower lip or chin, bearing a pair of jointed lip-feelers. The second jaws bear lip-feelers; an upper lip is usually present.

In association with the blood-sucking habit, the mouth parts of the mosquito (84: 4; 119) are profoundly modified. The upper lip is prolonged as a three-quarter tube, up which blood is pumped. The elongate, flattened tongue closes the tubular upper lip, and bears the salivary duct; the saliva reaches the victim and prevents the blood from coagulating.

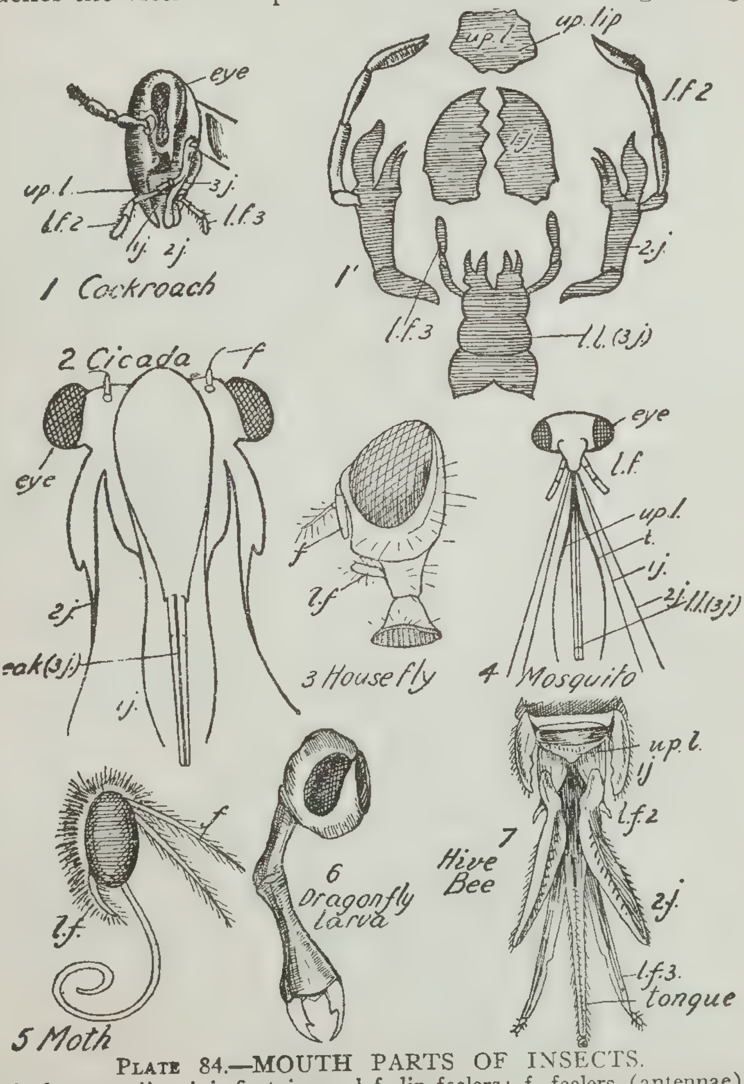


PLATE 84.—MOUTH PARTS OF INSECTS.
Up l, upper lip; i j, first jaws; l f, lip-feelers; f, feelers (antennae); l l, lower lip.

The first jaws are fine lancets; the second, saws; the third pair forms the lower lip, ensheathing and supporting the six piercers (upper lip, tongue, two lancets, and two saws).

The bee (84:7; 103) also has modified mouth parts. It has the first biting jaws, but the second and third jaws form a honey-gathering "tongue."

Some larvae have weapons of offence. The dragon fly larva has a remarkable "mask" (84;6; 97); this lower lip, armed with fangs, folds over the mouth when not in use (90:2). The water tiger, larva of the diving beetle (105:7) has terrible grooved fangs; it sucks blood from a victim while holding it tightly.

Sucking-beak insects, *e.g.*, Cicada (84:2; 122:4) have the first and second pairs of jaws modified into setæ, or lancets, working in the grooved proboscis or beak; these insects are parasites; some, Cicada and Aphis (123), are parasitic on plants; others, bed bugs (121:7) and water boatmen (121:11, 12; 87:14), on animals.

The housefly (84:3; 117:1^1) has a hollow, jointed trunk, folded away when not in use. The fly, taking only liquid food, dissolves food with the saliva. The salivary ducts branch in numerous tubes in the spreading end of the trunk. Butterflies and moths (84:5; 110:3^1; 111:3) have a hollow trunk formed of two equal parts. This is thrust into a flower and honey is sucked up; it coils up when not in use.

Insect legs, built on a common plan, show much diversity of structure in association with various life habits. The leg has five parts (85:1). The first part (coxa), joining leg to body, is usually small, though in the Mantis (85:3; 94:2) it holds the "fly trap" well away from the body and allows of its effective use; this part is large, also, in the cockroach. The small second part (trochanter) suggests a knee-cap. The third part (femur) is usually conspicuous. From analogy with a vertebrate leg, it is called the "thigh." It is large in the grasshopper's jumping leg (85:19; 95:1^{11}) and is grooved in the fly-trap of the Mantis. The fourth division (tibia) is usually called the "shin," and the fifth part (tarsus) the "foot." There are five joints in the foot of cockroaches (85:1; 81:7) and ants (85:11; 102:4); four in katydids (95:3^1), three in grasshoppers (85:19) and Cicadas (85:10), two in Aphis, one in some scale insects.

The legs provide many interesting modifications. The flytrap of Mantis (94:2) and water-scorpion, *Nepa* (85:4; 121:8), is an effective organ of offence. In the diving beetle the male has on the front legs remarkable pads with suckers (85:5), a clasping organ to hold his mate's enamelled back.

Water insects often have flattened legs fringed with hairs (85:12, 14; 121:11); their legs are swimming paddles. The whirligig beetle, *Gyrinus* (85:6, 7; 105:6) has perhaps the most highly developed swimming legs.

The mole cricket has the front shin (85:9; 96:2[1]) much expanded; and terminating in four fingerlike processes; it

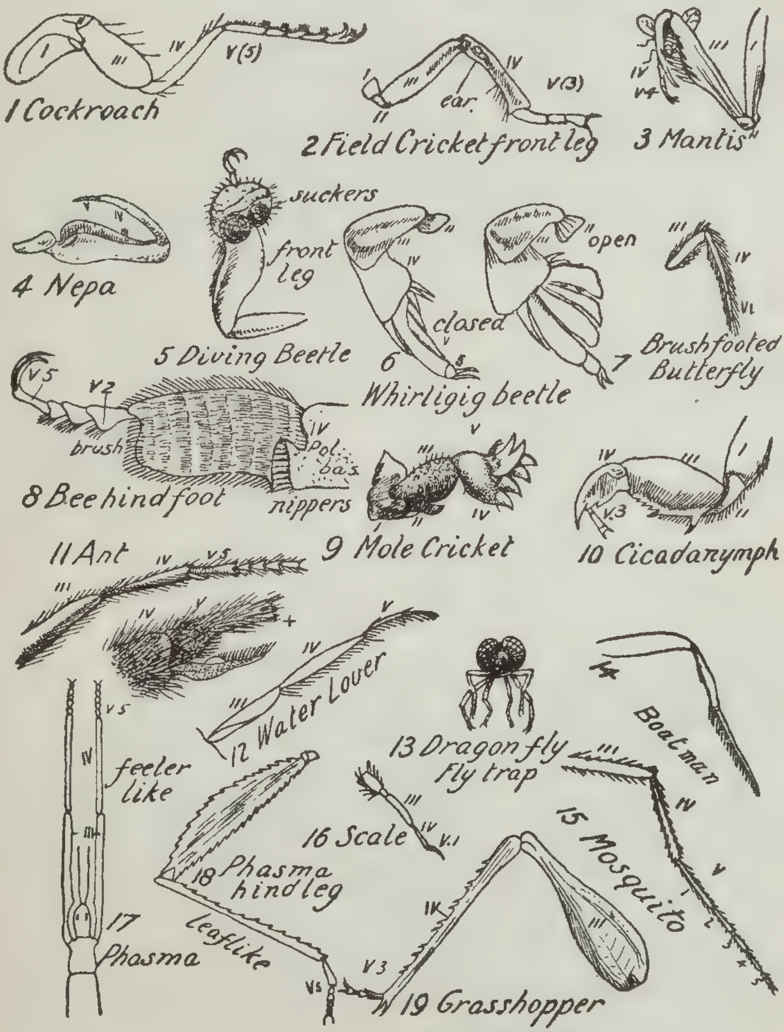


PLATE 85.—LEGS OF INSECTS.
I.-V., No. of part of leg; 1-5, No. of joints in foot.

acts as a shovel. The foot has two strong pointed processes, and rotates on the shin, forming an effective shears.

The Cicada nymph (122: 8; 85: 10), living so long underground, has a strong digging and cutting ("fossorial") foot. Bees (103), ants (102: 4), and wasps (101) have on the front legs brushes which clean the delicate sensitive feelers. The first joint of the worker bee's hind foot (103; 85: 8), wide and hairy, brushes pollen from the body; this is placed in the pollen-basket, the swollen part of the "shin." Between pollen-basket and brush is the "wax-nipper," and on the shin is a comb. The front legs of *Phasmids* (85: 17; 94: 1), notched to fit round the head, are directed forward and serve as feelers; the flattened hind thighs (85: 18) with serrated edges mimic a leaf, and probably assist in escaping notice.

The grasshopper's jumping leg (85: 19) is a wonderful organ. Long to give increased leverage, strong and broad to accommodate the large muscles, provided with spikes like a runner's shoes to prevent slipping, and furnished with pads like rubber heels to reduce jar on landing, it is perfect. A row of pegs along the inner side of the thigh is played over by the stiff vein of the wing-cover and forms a musical instrument for the male. The mosquito's long, needle-like feet (85: 15; 119) rest on the water and support its weight. The six legs of the dragon-fly (85: 13; $97:2^{v}$) form a fly-trap. Crickets (85: 2; $96: 1^{iv}$) and long-horned grasshoppers ($95: 3^{i}$) have the ear on the front shin.

Wings contribute much to the insect's success in life. It is by their wings that scientists classify insects.

Insects are divided into two sub-classes, according to the absence or presence of wings. Sub-class 1 contains those insects that are entirely wingless throughout life. They form the first small order—wingless insects, *Aptera* (*a,* not; *pteron,* a wing). Silver-fish or bristle-tails (92: 2) and spring-tails (92: 1), are included. Winged insects form the large second sub-class. These are divided differently by different authors. The classification of Mr. Froggatt in "Australian Insects" into eight orders is here followed. Members of the second order of insects have two pairs of wings; the front wings, narrow and horny, form wing covers for the delicate flying wings, which fold fanwise along straight veins, hence the name straight-winged insects,

Orthoptera (*orthos*, straight). This is an important order to nature-students, as the insects, *e.g.*, crickets (96) and grasshoppers (95), are large and common. The third order is characterized by lace wings with strong veins or nervures (not sensitive nerves). It contains the nerve-winged insects (97-99), *Neuroptera* (*Neuron*, a nerve). This is a collec-

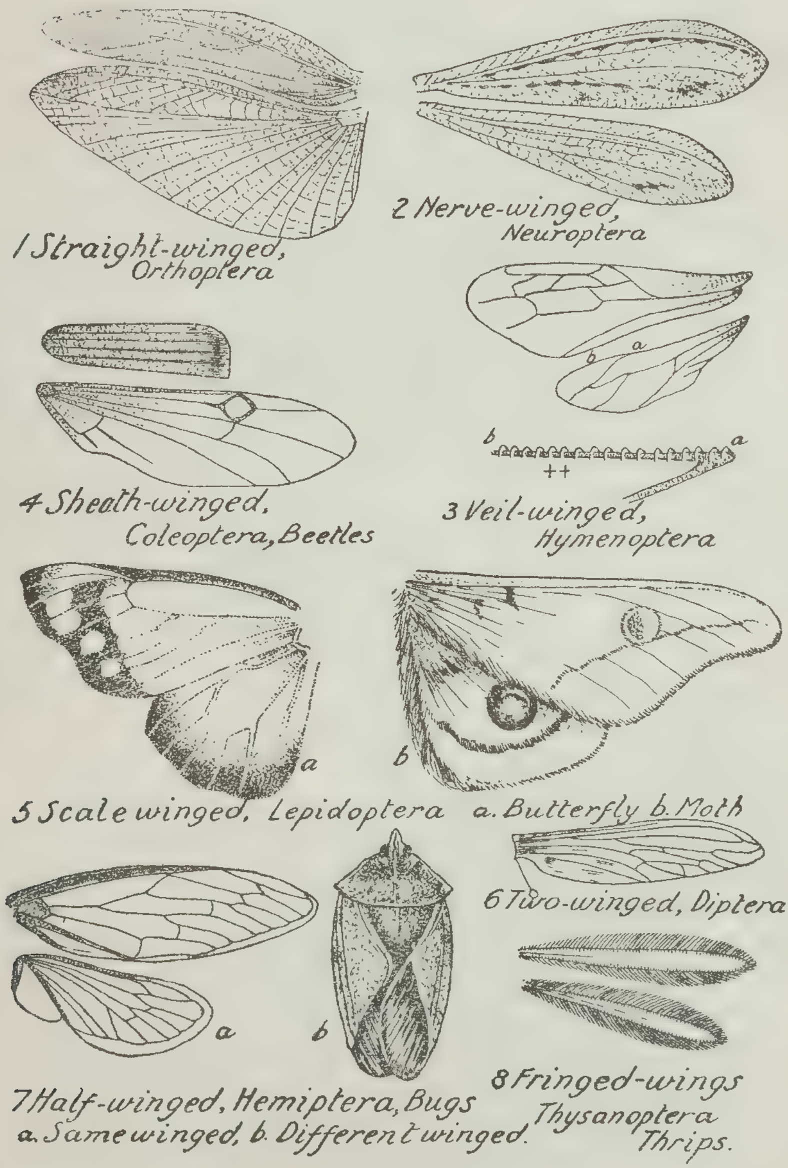


PLATE 86.—WINGS OF INSECTS.

tion of insect families often divided into several orders. Insects of the fourth order, including ants (102) and bees (103, 104), have four membranous flying wings, though some individuals are wingless. These are not grouped with the *Aptera,* but with their relatives. The fore and hind wings may be joined by means of hooks. Insects of this order are called veil-winged or joined-winged insects, *Hymenoptera.* (Hymen, god of marriage.) The name may refer to the veil wings or possibly, to the joining of the wings. Other insects, *e.g.,* butterflies and moths, also may have wings joined, but do not belong to the *Hymenoptera.* Beetles (105-107) form the fifth order. The hard upper wings shield the membranous flying wings. The order contains the sheath-winged insects, *Coleoptera* (*koleos,* a sheath). Usually, the upper wings (105: 5) are hard; they meet down the centre of the body in a straight line and fit close to the sides. This is a large order; many are expensive pests, while others are beneficial. Butterflies and moths (86: 5a, b; 108-116) form order six. The wings and body are clothed with scales, hence the name, scale-winged insects, *Lepidoptera* (*lepis,* a scale). Insects of order seven (86: 6; 117-120) have one pair of wings, the second being reduced to knobs or balancers. These two-winged insects, *Diptera* (Greek word for two-winged), are usually called flies, though this name is used in other orders also. Mosquitoes (119, 120) and house-flies (117: 1) are well known. The sucking-beak insects (86: 7a, b; 121-123) present a difficulty. One sub-order, including Cicada and Aphis, has the four wings membranous and the front wing (87: 7a; 122, 123) the same throughout; it is called *Homoptera* (*homos,* same). In the other sub-order, the front wing (87: 7b; 121) is different from the second, and the inner half is horny but the outer half is membranous; the sub-order is called *Heteroptera* (*heteros,* different). The name *Hemiptera* (*hemi,* half) used for the order, is not applicable to the *Homoptera.* The name "sucking-beak insects" is often used instead of "Half-winged insects." Thrips, small yet destructive in gardens and orchards, have fringed wings (86: 8; 123: 9). They form the ninth order, fringe-winged insects, *Thysanoptera* (*thysanos,* fringe). Thus, based mainly on the wings, there are nine orders of insects.

CLASS INSECTA OR HEXAPODA.

Sub-class	I.	Wingless Insects.
Order	1.	Aptera, no wings, Silverfish.
Sub-class	II.	Winged Insects.
Order	2.	Straight-winged Insects, Cockroach.
,,	3.	Nerve-winged Insects, Dragon fly.
,,	4.	Veil-winged Insects, Ant and Bee.
,,	5.	Sheath-winged Insects, Beetle.
,,	6.	Scale-winged Insects, Butterfly.
,,	7.	Two-winged Insects, House-fly.
,,	8.	Sucking-beak Insects, Cicada, Boatman.
,,	9.	Fringe-winged Insects, Thrips.

The breathing system of insects is highly developed. Air goes throughout the body; there is no lung or gill. A spiral thickening, keeping the thin-walled air-tubes (87:2) open, suggests the wire inside a gas tube or the cartilaginous rings of the windpipe (trachea); the tubes are called "tracheal tubes," and the insect breathes by means of a "tracheal system." The tubes divide and divide again until their fine branches reach every part. Usually there are two or four breathing holes (87:1) on the chest, and usually one pair on each ring of the body except the last. All adult insects breathe air—none breathes water, *i.e.*, obtains air from that dissolved in water as a fish does. So highly developed is the breathing system that the blood-circulatory system is poorly developed. The heart runs along the back; it contracts from behind to the front, the blood circulates forward on the upper side, down and back on the underside. The dark pulsating line along the back of the silkworm or Gum Emperor caterpillar is the beating heart. Many water insects come to the surface; some take down a bubble (87:8) of air, a few, Nepa (87:10; 121:8) and Ranatra (87:16), have a long breathing tube which reaches the surface. Mosquito larva (87:13a) and pupa (87:13b) and water tiger (87:4) breathe air direct. The rat-tailed maggot (87:6) larva of the drone-fly (*Eristalis*) (118:4) has a telescopic breathing tube. The soldier-fly or chameleon-fly larva (87:5; 118:8[1]) has a coronet of hairs.

Insect larvæ often "breathe water." The dragon-fly larva (87:3; 97:1[1]) takes water into the end of the alimentary canal (rectal breathing). By forcibly expelling the water,

it moves forward. The damsel-fly larva (87: 7; 97: 2ii) has three gill (tracheal) plates, the stone-fly larva (87: 9; 98: 2ii) has tracheal hairs on the chest, while the May-fly larva (87: 11; 98: 1) has a series of plates along the sides forming a "closed tracheal system." Caddis larvæ (87: 12; 98: 3i), like many other larvæ, keep water moving past the breathing organs to secure enough oxygen. A few pond animals, living where oxygen is not abundant, have red blood. The red is hæmoglobin, the oxygen carrier of our red

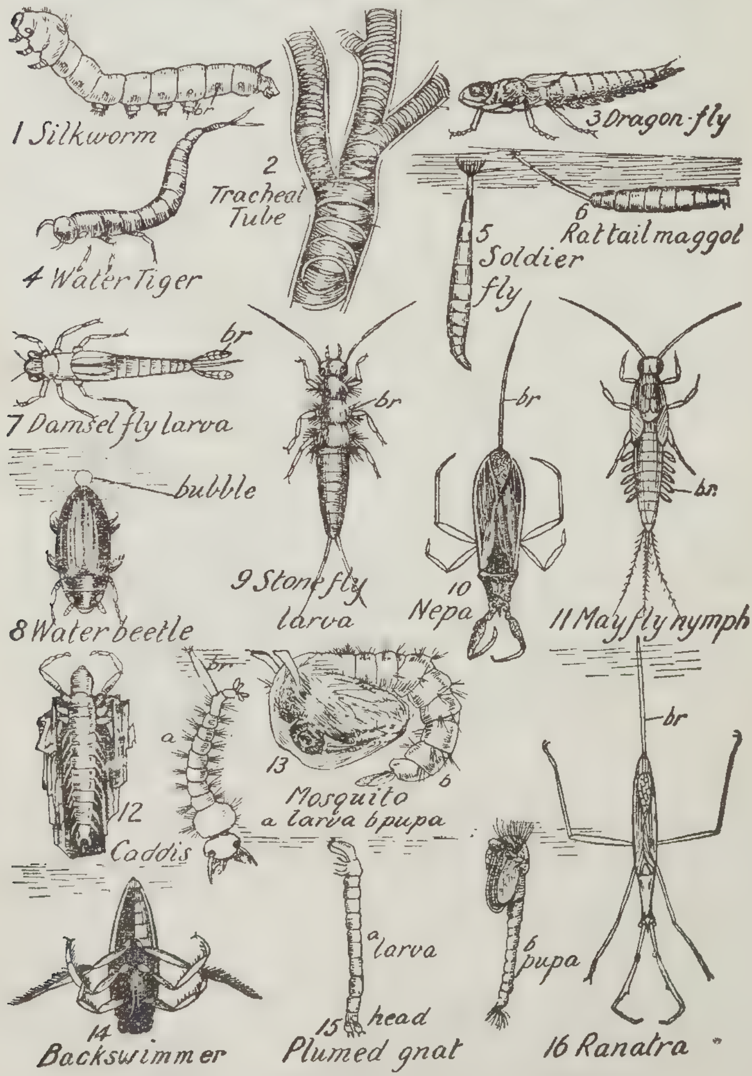


PLATE 87.—THE BREATHING OF INSECTS.
Br., Breathing Structure.

blood corpuscles. A red worm (*Nais*) is often seen in filthy water. The blood worm, the larva (a) of the plumed gnat, *Chironomus* (87: 15; 118: 1) is common. The plumed gnat, pupa (b) resembles the mosquito pupa, but it has breathing hairs instead of breathing horns.

In animals with bones, vertebrates, the sound-producing or voice-producing apparatus (88: 9, 9^{1}. 9^{ii}) is connected with the breathing system, and that again with the mouth or nose. The breathing of invertebrates is seldom connected with the mouth, and the sound apparatus is not connected with the breathing, except, perhaps, in the mosquito.

Male field crickets and mole crickets have a file (88: 1; 96: 1^{1}) on the upper wing and a scraper alongside it. By playing the scraper of one wing on the file of the other, the cricket produces the loud whirring noise. The male long-feelered grasshoppers (katydids) have a file (88: 2; 95: 3^{ii}) on the left and a scraper on the right wing cover. A semi-transparent membrane perhaps acts as a drum or sounding-board and increases the sound. The short-feelered grasshoppers (88: 3; 95: 1^{ii}) have pegs on the inner side of the

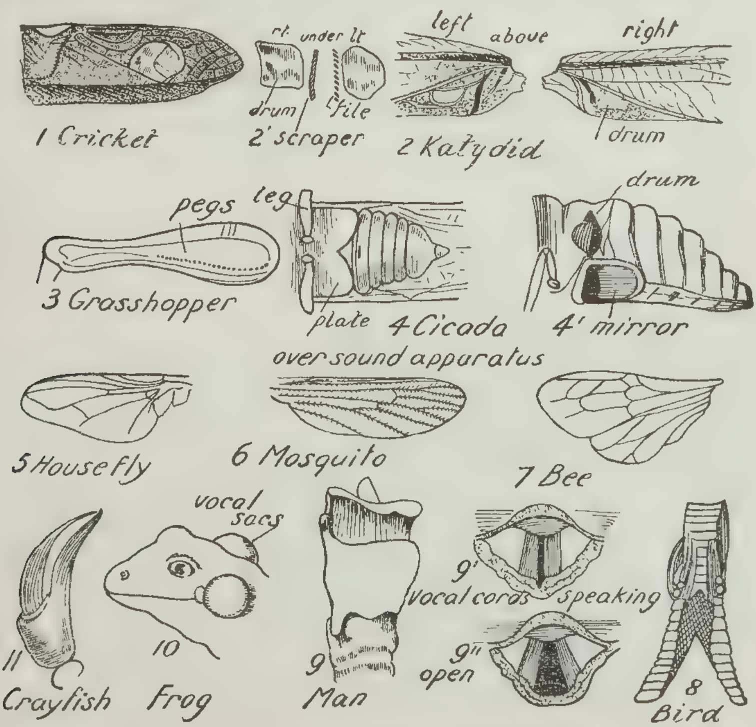


PLATE 88.—SOUND-PRODUCING ORGANS

The eggs of animals vary in size, shape, and number. The egg-raft (89: 1; 119) of the mosquito, common as it is, is still unknown to most people, though it may usually be found within a few yards of the home. The cigar-shaped

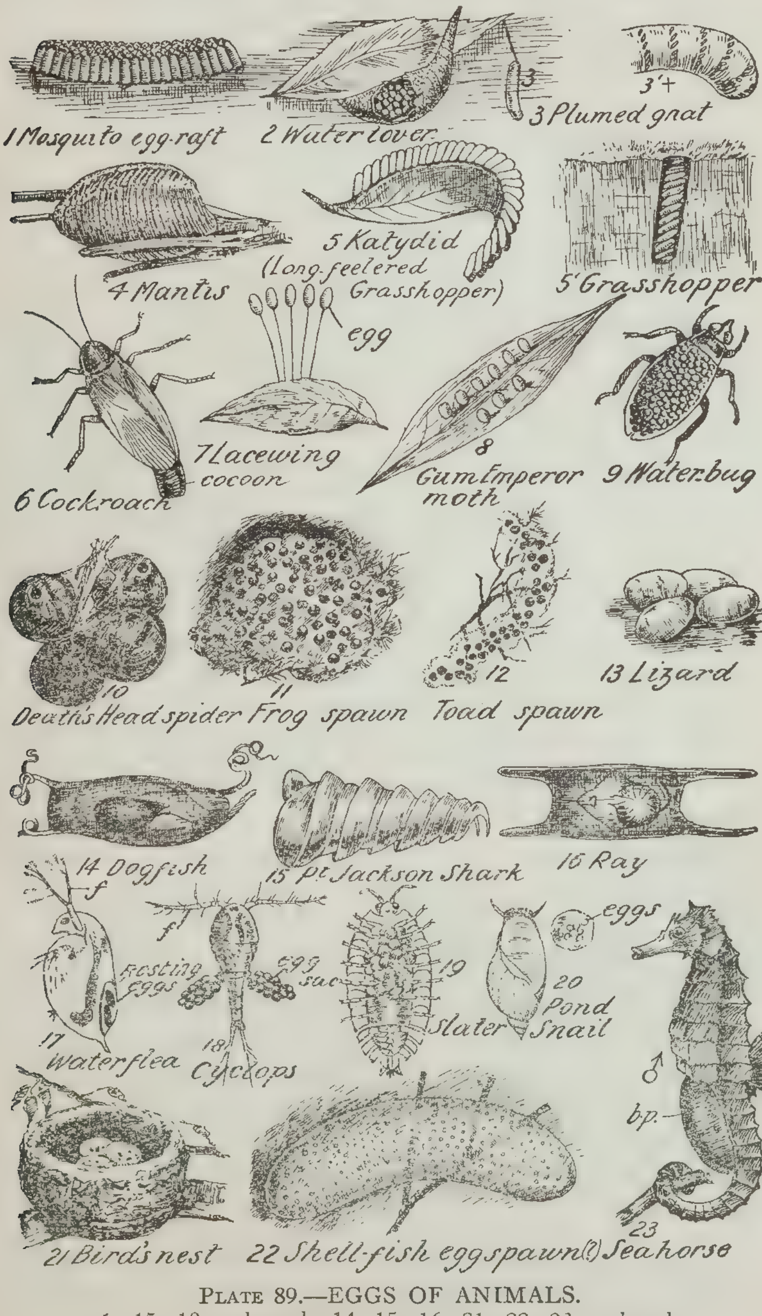


PLATE 89.—EGGS OF ANIMALS.
1, 17, 18, enlarged; 14, 15, 16, 21, 22, 23, reduced.

jumping legs; the edge of the wing-covers plays over these. The male Cicada has a perfect sound apparatus (88: 4, 4^1; 122: 2, 3) with a kettle-drum action; a "mirror" and a resonating chamber increase the sound. The hotter the day, the more persistent is this song, which is more fully dealt with under Cicada. Excepting mosquitoes, apparently only male insects make a noise, for females have no special sound organ. The buzzing or droning of beetle, fly, bee, and partly so of mosquito, is apparently due to the wings. In addition to droning, many beetles make a low filing noise by rubbing the end of the body on the sheath wings.

The "barking spider" of Central Australia rubs together the inner sides of the poison claws. A small, shrimp-like marine crayfish with one large and one small claw (88: 11) closes the large claw with a snap like the closing of a pocket knife. One male frog has vocal cords and sacs (88: 10) near the ears. These latter act as resonating chambers, and increase the sound made in the larynx; another kind inflates the skin of the throat. Mammals make a noise by means of the two vocal cords (88: 9, 9^1, 9^{11}) situated in the larynx. These, when stretched and parallel, are set in vibration by the breath. In addition to the larynx, a bird (88: 8) has a "syrinx" at the base of the windpipe and the upper ends of the bronchial tubes.

Insect *LIFE HISTORIES* are varied and interesting. Producing many eggs, the moth cannot give the care and attention bestowed on her chicks by a domestic hen. She does the next best thing by laying the eggs where the young find abundance of suitable food. Each insect has its special "food plant" or other place for the eggs. Often the growing or vegetative stage is entirely separated from the egg-producing stage, as in the silkworm, where the worm (larva) does the feeding for the whole life. The adult differs so from the larva that the whole animal has to be reconstructed, mouth parts and all, so that a stage where no feeding is possible is often found between larva and adult. This reconstructing defenceless stage is sometimes spent in a cocoon or puparium hidden from enemies.

eggs adhere, forming a raft (they are not laid *in* a raft). A plumed gnat lays its eggs in a long string like a string of sausages enclosed in a jelly mass (89: 3) and anchored to a twig a little below the surface of standing water. The water-lover beetle (89: 2; 105: 8^{i}) lays many eggs in a cocoon with a pointed end (mast); the cocoon is attached to weeds. Cockroach (89: 6; 81: 8) and Mantis (89: 4; 94: 2^{i}, 2^{ii}) lay eggs in rows in a papery cocoon. Spiders lay perhaps 150 eggs in a silk cocoon. The ground spider often carries the cocoon about with her. The death's head spider, mimicking a bird-dropping, sits on its half-dozen figured egg-cocoons (89: 10; 129: 5) and usually escapes notice.

Many insects lay their eggs a few at a time on the food plant; it is not wise to put all the eggs in one basket. The vine moth lays a few here, a few there. The gum emperor moth lays a dozen (89: 8; 112) in a row. Long-horned grasshoppers, katydids (89: 5; 95: 3^{iii}), arrange the flat eggs along a leaf. Grasshoppers (89: 5^{i}; 95: 1^{iv}) burrow and lay their eggs in the ground. The Cicada (122: 6) thrusts the egg-placer through the bark and lays several eggs there. Ichneumon flies (100: 4^{i}) lay their eggs in other insects and their larvæ. Each egg of the lace-wing (89: 7; 99: 2^{i}) is on a long rigid thread.

On the beach one often finds a large, clear, sausage-like mass of jelly; looking closely, one sees minute white eggs (89: 22) all through it. Though usually called a jelly-fish, it is the egg-mass of a shell-fish, and reminds one of frogs' spawn (89: 11; 139: 1) floating in a pool, or, in cold weather, resting transparent below on a rush or twig. The toad (89: 12: 139: 17) lays similar eggs in a long strand resting on pond vegetation. Reptiles (lizards and some snakes) leave soft-shelled eggs to be hatched by the warmth of the sun.

The pond snail (89: 20; 132: 3) lays her eggs in a small gelatinous disc on the side of the glass aquarium. Maternal care is shown by many of the lower animals.

Daphnia, the water-flea (89: 17; 79: 9) and the minute *Cyclops* (89: 18; 79: 4) carry the eggs in egg-sac or brood pouch. The slater (89: 19; 79: 10^{i}) also carries the eggs about; while Zaitha, the egg-carrying bug (89: 9; 121: 13) carries them on her back. Most remarkable perhaps is the small seahorse (89: 23; 138: 6): the male carries the eggs

in a small brood-pouch. Birds' eggs and nests (89: 21; 150) are more fully discussed later. Some of the cartilaginous fish (sharks) lay eggs (89: 14-16; 137) that have a horny shell of chitin; though at first attached to weeds, these eggs can stand a certain amount of buffeting in stormy waters.

The young larvæ emerging from eggs may resemble the parents, but are usually different. If the food supply is abundant, there is no need for thought in finding it or

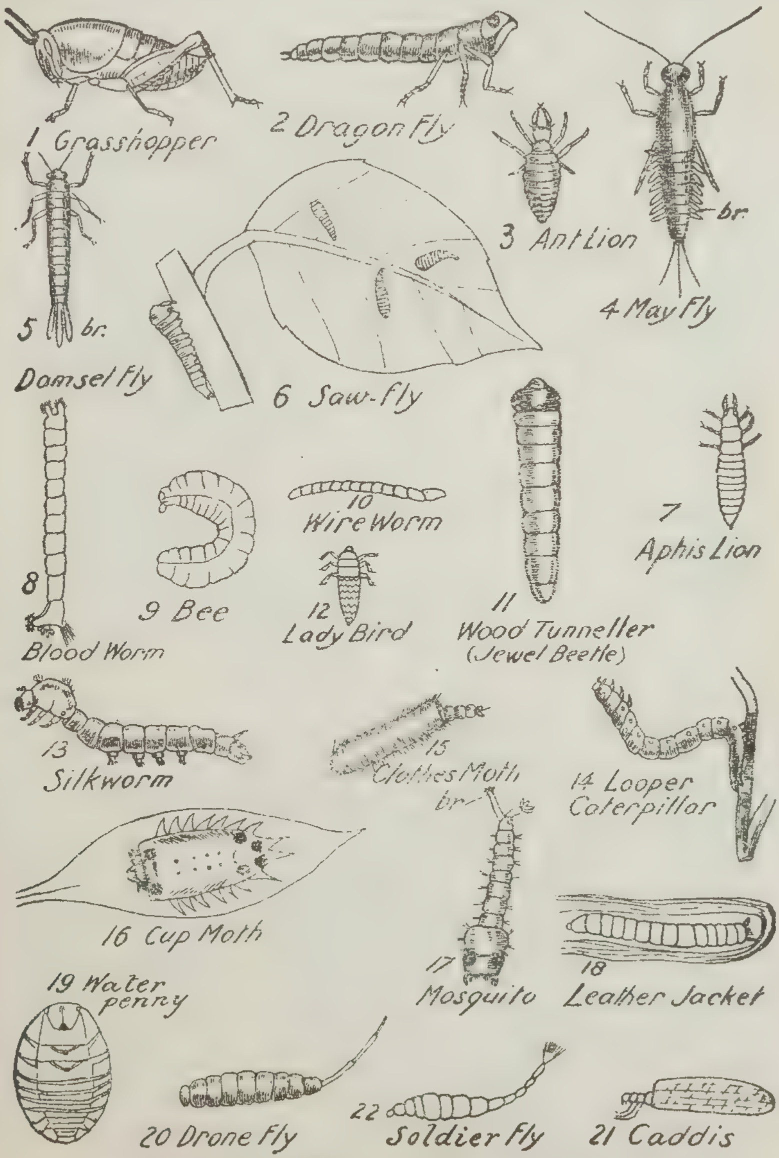


PLATE 90.—LARVAL FORMS OF INSECTS.

locomotion to secure enough; this happens with the larvæ of bee, ant, and house-fly; larvæ so favorably placed become shapeless, headless and footless maggots. Their conditions are so easy that they have degenerated; still it is possibly an advantage to the race. They are able to concentrate on the business of eating, and pass more rapidly to the later stages. Grasshopper, cockroach, and cricket larvæ lead lives somewhat similar to those of the adult, and resemble the adults. Dragon-fly, May-fly and damsel-fly larvæ live in water; a long life in a dingy pool in preparation for the free aerial life later. The "closed tracheal" breathing system has made May-fly larvæ famous. The ant-lion larva (90: 3; 99: 1^{i}) in its trap (1^{iv}) is one of the marvels of the animal kingdom. The aphis-lion, "old clothes man" (99: 2^{ii}), cousin of the ant-lion, is an interesting animal of the garden; it is the larva of the golden-eye, or lace-wing, a "beneficial insect." Dressing itself in the skins of its victims, the larva becomes a favorite with nature writers. The soft larvæ of some saw-flies, e.g., gum-leaf saw-fly, are "pear slugs" (90: 6; 100), so destructive to the leaves of hedge plants and fruit trees. Vine caterpillars (114: 5^{i}) and many others are well-known pests.

The wire-worm, larva of the click beetle (106: 7), is often confused with leather-jacket (90: 18; 117: 4^{i}) larva of the crane-fly (*Tipula*), and even with the millipede (80: 4). All three are destructive to plants.

Caterpillars (90: 13; 115: 1), *e.g.*, silkworm, have usually five pairs of cushion legs ("pro-legs") and three pairs of true legs; looper caterpillars (90: 14; 113: 3^{i}), however, have only two pairs of pro-legs. These animals mimic a twig, and remain stiff. They move by looping the body up, and then stretching out. Some moth larvæ make cases or bags. The casemoth larva (116: 1-4) is common. The clothes-moth larva (90: 15) has a similar habit, though living in clothing; it apparently does not need a case either for warmth or for protection. However, it makes one often from a costly garment. Caddis larvæ (90: 21; 98: 3) have been called water case-moths; they have remarkable and varied cases. Cup-moth larvæ (90: 16; 114: 4), "stars," have eight bunches of stinging hairs. When not expected, the severe stings suggest a powerful stinging nettle.

The "water penny" (90: 19) is a remarkable insect larva found under stones in running streams; it is the larva of a

PLATE 91.—NYMPHS, CHRYSALIDS, PUPAE, AND COCOONS.
13, 14, 16, 18, enlarged.

beetle. Mosquito larvæ (90: 17; 119), feeding with one end of the body and breathing with the other, are familiar to all. Rain tanks, broken bottles, old tins, any standing water, serve as living places for these active larvæ. Blood-worms (87: 15), rat-tailed maggots (87: 6; 90: 20), and larvæ of the soldier-fly (87: 5; 90: 22) have already been mentioned. The "nigger," a larva (90: 12; 107: 8) of the carnivorous ladybirds, will further indicate the variety and interest of a study of invertebrate larval forms.

The stage intermediate between larva and adult may be a quiet pupal stage with no feeding and no locomotion. The animal, swathed round like a doll, is called a pupa. It is usually hidden away in a puparium or cocoon. Most beetles (91: 9), moths (91: 12), house-flies (91: 18), ants (91: 8), and bees (91: 14) have such a pupal form. The ant-lion makes a spherical cocoon of silk and sand-grains (91: 4; 99: 1^{ii}, 1^{iii}). As the animal is being reconstructed, this is strictly not a resting stage. Instead of being enclosed in a cocoon, the animal, as is the chrysalis of the butterfly (91: 10; 11), or ladybird (91: 13), may be exposed. Butterflies remain uncovered in this "chrysalis" stage, attached by the tail, some being supported also by a silk girdle.

Clothes-moth and case-moth larvæ close up the old larval dwelling (90: 15; 116), and use it as a puparium. The so-called "ant-eggs" carried off when an ant-nest is disturbed are usually larvæ or cocoons (102: 7), containing pupæ. Many larvæ, *e.g.*, saw-fly (100: 1^{iii}; 91: 6), and vine moth, burrow into the ground before pupating. The active mosquito pupa (91: 16; 119) moves freely to escape enemies.

Other animals at this changing stage remain active. They move and feed as the larvæ did, but show conspicuous wing outgrowths; such forms are "nymphs." The name is sometimes used for the larval stages of insects (*e.g.*, cockroaches) where the larvæ resemble the parents except in size and absence of wings. However, "nymph" is used here for the stage preceding the adult when it is an active feeding stage. May-fly (91: 1), mantis (91: 2), grasshopper (91: 3), damsel-fly (91: 5), dragon-fly (91: 7); Nepa (91: 17), and Cicada nymphs (91: 15; 122: 7, 8) are illustrated.

INSECTS OR THE SIX-FOOTED; HEXAPODA.

Insects are animals having three main parts and six jointed legs. The head bears eyes, mouth parts, and one pair of feelers; chest, composed of three segments, bears six legs; and usually wings, two pairs or one pair, though wings may be absent in insects of any order; and the body or abdomen bears no jointed limbs.

Insects, as already seen, are classified in nine orders according to the number and kind of the wings.

Order 1. *Wingless Insects.—Aptera* (*a* not, *pteron*, wing). These insects never develop wings; the young resemble the parents except in size. There are two groups of these, which are fairly common, and a third rare group.

(i.) *Spring-tails* (92: 1; 187: 4, 4^1), often seen as a blackish powder on the surface of temporary water.

(ii.) *Silver-fish* (silver lady, or silver moth) (92: 2) are common in some houses where they often damage the binding and paper of books, and the paste of the wall-papers. On account of the cerci, or bristles, at the end of the abdomen, they are sometimes called "bristle-tails." They are called fish insects, from the small scales that cover them.

(iii.) *Japyx* (92: 3), a large insect over an inch in length, is somewhat like an earwig in general appearance. It was found under stones and logs in the Grampian Mountains,

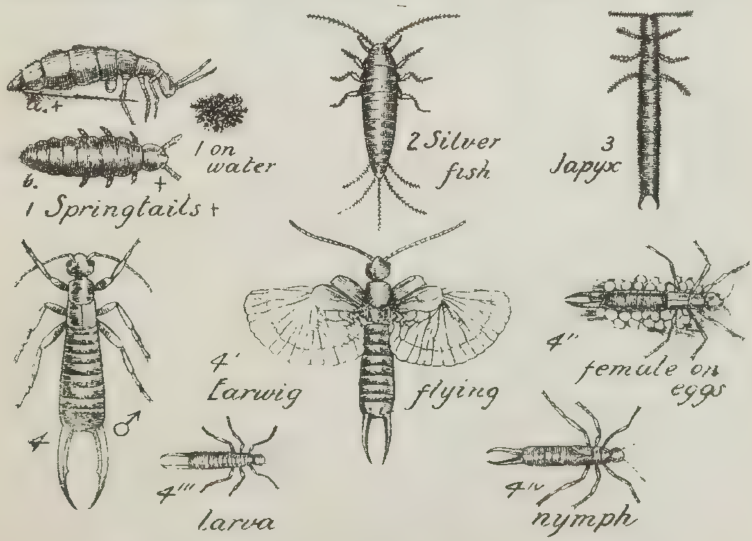


PLATE 92.—WINGLESS INSECTS AND EARWIG.
1, Springtails; 2, Silver-fish; 3, Japyx, 4, Earwig

Victoria. Though rare and wingless, it has been recorded from Africa, Malaysia, Australia, Mexico, and Europe.

Order II. *Orthoptera,* straight-winged insects.— These insects (usually large) have biting mouth-parts; the upper wings are narrow, and form wing-covers, protecting the flying wings and the back. The delicate lower wings fold fanwise along straight veins. In some Phasmids, leaf insects (94: 1), however, the front portion of the hind wing is hard, and, where it is not covered by the wing-covers, is protectively colored. Straight-winged insects undergo only slight changes until they assume the adult form. At birth they resemble the parents, except in size and wings. There are four larval stages and an active nymph stage before the adult form is assumed. Many insects of this order have the wings small or absent. With the exception of the carnivorous Mantids (94: 2), all are said to be vegetarians, though earwigs (92), and crickets (96) may eat dead insects.

There are eight families suitable for nature-study in this important order; they are grouped as Runners and Jumpers.

Order II.—*Straight-winged Insects.—Orthoptera.*

(a) Runners, graspers and walkers, five families:—

1. Earwigs (92: 4). 2. Cockroaches (81: 1-10). 3. Termites, white ants (93: 1-8). 4. Mantids, praying insects (94: 2). 5. Phasmids, leaf and stick insects (94: 1).

(b) Jumpers or Leapers, three families:—

6. Short-feelered Grasshoppers (95: 1, 2). 7. Long-feelered Grasshoppers (95: 3). 8. Crickets (96: 1, 2).

The males of the second group are musical. The members of the first group are dumb, or make little noise. Though (in some families) the males have the advantage in sound, the females, in others, *e.g.*, Phasmids and Mantids, are larger and brighter than the small, plain, sometimes differently-shaped males.

Harmless *EARWIGS* (92: 4) strike a "terrifying attitude" by bending the back and spreading the forceps, pincers or callipers, as the strange processes at the end of the body are variously called. Some people call earwigs scorpions, and many fear them. In spite of their evil reputation, they are harmless, and probably valuable insects. They avoid light, and seek shelter by crawling under logs and bark.

Twenty of the 500 widely-spread species have been

recorded from Australia. The earwig is said to be the commonest insect in England. The two short wing-covers (92: 4) meet in a straight line in the center of the back, as in beetles. Earwigs can be distinguished from beetles by the forceps, larger and often more complicated in the males.

The large under-wings (92: 4[1]) are ear-shaped when expanded. They fold fanwise, and then fold twice across. They are folded under, but project slightly from, the wing-covers. Earwigs are said to use the forceps to close the wings, but even wingless earwigs have forceps. The writer has seen the wings fold automatically, but they were spread with the aid of the forceps.

Earwigs are said to eat petals of flowers such as carnations and Dahlias. Other observers record earwigs as eating dead insects, larvæ, and small snails. They are credited with much care of eggs and young. Being cold-blooded, the female does not sit on the eggs to keep them *warm,* as some writers state. Possibly she protects them from an enemy. Earwigs resemble rove beetles (106: 2, 2[1]), but the latter have no forceps. Young earwigs resemble the adults, except for size and wings. The structure of earwigs agrees with that of other straight-winged insects. The abdomen contains ten segments, though only eight are visible externally in females. On account of the peculiar structure of the wings, some authorities place earwigs in an order by themselves—the Dermaptera (skin-winged).

Brown *TERMITES* (93: 1-9; 126: 2), though called white ants, are not white, nor are they ants. Possibly no two groups of insects are more unlike, except in social life, than ants and termites. Ants have tight-fitting armor, termites are soft-bodied; ants have a constriction in the body, termites have none; ants have a sting, termites have none; ants devour termites whenever they meet them. Termites live in warm countries; Australia, including Tasmania, has thirty-nine species. Possibly no other insects do more damage than termites. They are blind, and avoid the light. Working under cover, they are seldom seen, and the damage is usually serious before it is suspected. The social organization is as complete as that of ants; their well-founded colonies may contain thousands of termites; their chief food is wood; they will eat a beam,

leaving the outer shell as thin as paper. They are forest scavengers, eat refuse and assist in breaking down dead matter, thus allowing it to be used "over and over again." They do their "bit;" death and decay are necessary for life.

The queen (93:5) is said to lay sixty eggs a minute, or over 80,000 a day. Like the male (93:2), she was winged, and was driven from the home by workers and soldiers. Possibly, of all that left the nest, but five or six pairs return, or are found by workers and assisted to form colonies. The wings soon break off at a special suture. The queen then grows—it is unusual for adult insects to grow. She becomes enormous, although head and chest remain at their original size. She probably lives many years. The colony depends on her; but, in case of her death, several "reserve queens" are kept. The workers are larvæ, nymphs (93:7), or wingless, undeveloped adults of either sex. The soldiers (93:3)

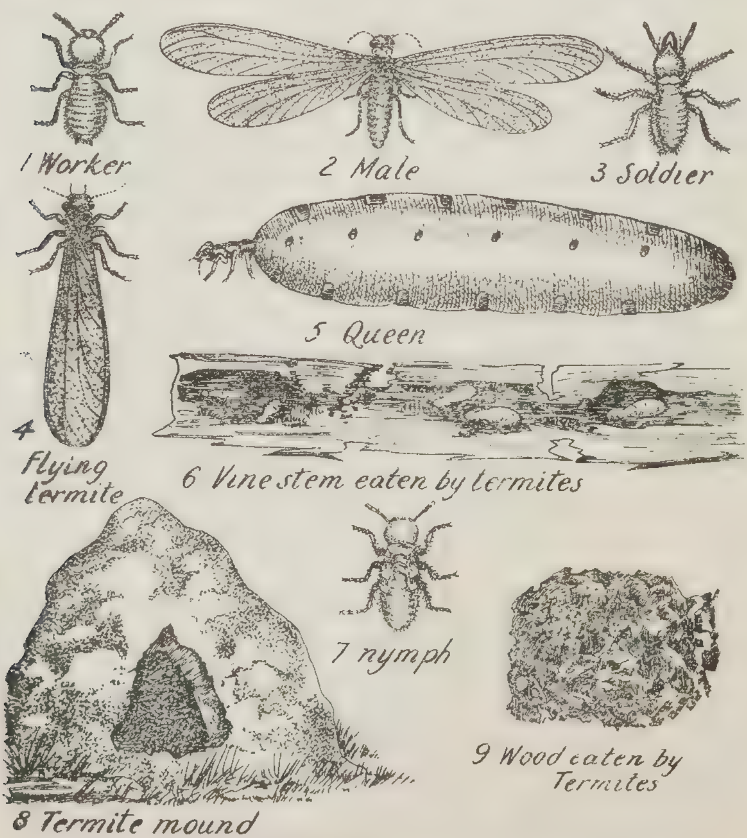


PLATE 93.—TERMITES (Wrongly Called White Ants).

also show "arrested development"; they have enormous jaws. Kings and queens have large heads, compound eyes, and two simple eyes; the wingless workers and soldiers have no eyes. The feelers have bead-like joints. The biting jaws being toothed and "steel-like," no wood is too hard for them. The long, oval wings are all alike, and, when at rest, overlap; they have simple, and, on the whole, straight veins. The home is clean; all refuse is eaten and re-eaten until nothing more can be digested from it; cast skins, and even dead termites, are eaten. The final residue is used for building the home. Many termites have been poisoned. Arsenic is eaten by some, the dead bodies are eaten, and others are killed. "Rectal food" is their favorite food. The larvæ are like the parents, and moult several times.

In some way, termites communicate sound; this is probably produced by jerking the head against the chest. The "ears" are on the front shins, as in crickets and katydids.

Termites are long-lived, taking from eighteen to twenty-five months to reach the adult form. The young are all born alike; apparently, the type of food determines the ultimate form. Workers, soldiers, reserve queens, or winged forms are produced as required. All is done for the colony. The individual, as such, is not considered. Their habits render study difficult. Several species may live together; some may be "guests." Vines, fruit-trees, and potatoes have been attacked by termites. Termites are said to taste like sugared cream, and negroes are fond of them.

Large termite hills or mounds (93 : 8) are common in parts of Australia, including Eastern Victoria. Queensland houses are built on long blocks, covered with a tin-plate dish.

Man has assisted termites to spread. A captured slave-ship was dismantled at St. Helena; the introduced termites proved expensive pests. At La Rochelle, in France, even the archives were destroyed by introduced termites.

Formerly termites were classified with nerve-winged insects (*Neuroptera*); Froggatt places them with straight-winged insects (*Orthoptera*); other writers have made a separate order, *Isoptera* (*isos* equal) from the similar wings.

Few insects have attracted such notice as the *MANTIS* —praying insect, soothsayer, diviner, mule-killer, rear-horse, lady's finger, forest lady, preacher, prophet, or

insect-tiger. Mantids had the "sympathetic respect of religious people in the more ignorant ages." They are said to be worshipped by the Hottentots. The Mantis (94: 2) was said to point the correct way to travellers. In South Africa, it was thought lucky for a Mantis to be on one.

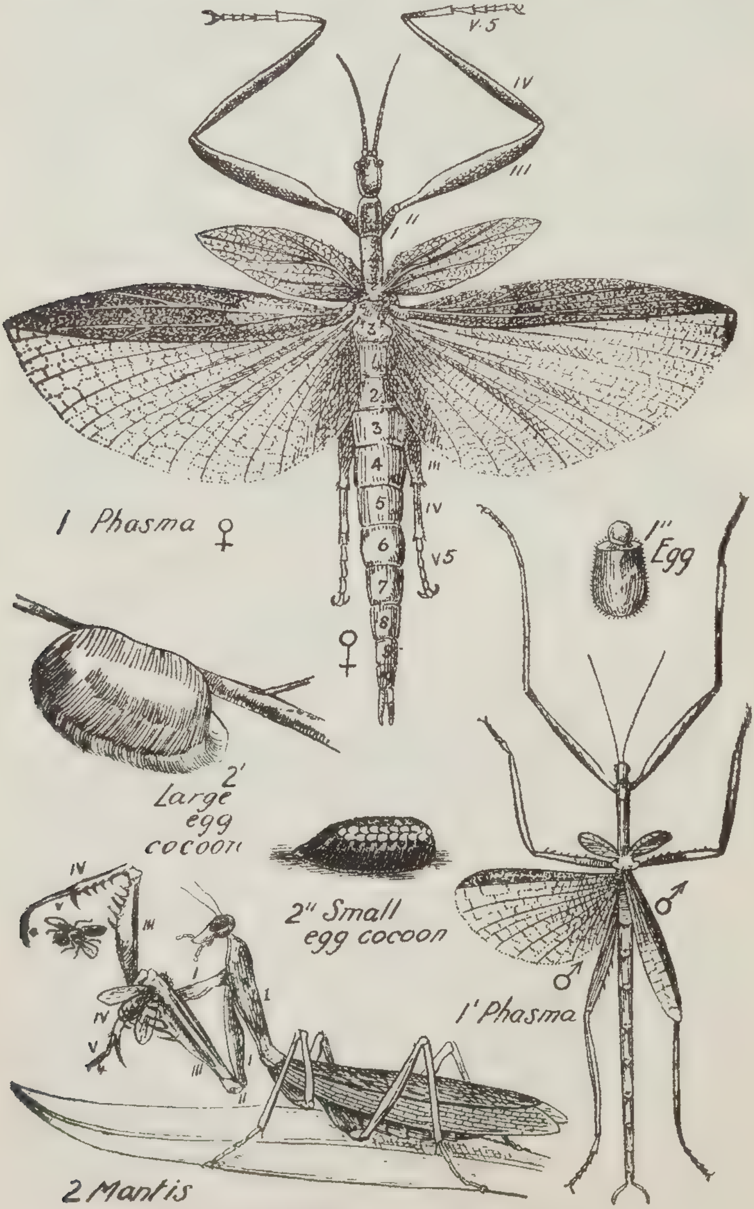


PLATE 94.—PHASMA AND MANTIS.
1, Female; 1[1], male.

Mantids inhabit warm countries. Australia has 35 kinds, but Britain has none, though occasionally eggs are introduced. The carnivorous Mantis has a long fore-chest, and remarkable front legs (85: 3), which are terrible weapons of offence; these are not often used in walking. The large insect lurks for prey with front legs in a praying attitude; its color harmonizing with its surroundings. The common species of Southern Europe is *Mantis religiosa.* The head and fore-chest are often semi-erect; hence the American name, rear-horse. The hind wings fold fanwise along straight veins, and are protected by the wing-covers, which often resemble leaves. Some Mantids have a peculiar shape; these "mimic" leaves and other parts of a plant. Mantids stealthily approach an insect, and seize it with lightning-like rapidity. A South American Mantid is said to eat small birds. The large, broad head has two compound eyes, three simple eyes, and jointed feelers. The head, which is bent under, has the usual biting mouth parts. It is joined to the chest by a neck, and turns easily.

The chief feature is the seizing front legs; the fourth and fifth parts of the front leg fold on the spiny third part, as a knife blade folds into the handle, the first joint is long, enabling the creature to use the weapon freely. A similar seizing leg is found on a crustacean, *Squilla mantis* (78: 9), a nerve-winged insect, *Mantispa* (99: 3), and some water-bugs, *e.g.*, water-scorpion, *Nepa* (121: 8).

This ferocious and voracious animal slaughters indiscriminately, the female having been known to kill its mate. Though it belies its reputation for piety, it is a valuable insect-destroyer.

The body shows nine parts above; below, eight parts are seen in the male, and six in the female. There are jointed tail-feelers. Mantids breathe through holes on the sides of the chest and body. No sound apparatus or ear has been described, though mournful or hissing noises have been recorded for some species. A blue spot on the front thigh has been mistaken for the ear. The males are slender, with small head and legs and long wings. Mantids are pugnacious, fighting with "unequalled ferocity." Chinese children keep them in little bamboo cages to fight other Mantids.

The smaller Mantid leaves the hard, brown egg-cocoon ($94:2^{ii}$) on a fence or shed; the large kind attaches the papery egg cocoon ($94:2^{i}$) to a twig. The numerous young resemble the parents; after five moults, the adult appears.

The Phasmids (94:1) ghost insects, or leaf-insects, are vegetarians. The heavy-bodied females are very different from the narrow elongate males. The short wing-covers mimic leaves exactly in color and markings. The front part of the under flying wings presents an unusual feature in that it is hard and stiff, and is protectively colored and marked except where covered by the wing-covers. Here it is brightly colored red or blue. Possibly this is a recognition color to enable its mate to recognize quickly the red-shouldered or blue-shouldered Phasma. When pursued by a bird, the insect drops amongst leaves, and there is nothing to be seen; hence the name ghost-insect (*Phasma,* an appearance or apparition). Some Australian flightless forms, walking-sticks or spectres, are over a foot in length, and are amongst the giants of the insect world. The front legs (85:17), hollowed to fit round the head, serve as feelers, the real feelers (antennæ) being short. The hind thighs (85:18) in the female are broad and serrated; the foot has five joints; the second division of the chest (82:C3) is large. The very delicate, tinted, large flying wings fold fanwise. The single smooth oval egg ($94:1^{ii}$), falls to the ground.

The short-feelered *GRASSHOPPERS* (95:1, 2) belong to the family *Acrididae,* while the long-feelered grasshoppers (95:3, 4) belong to the family *Locustidae.* The short-feelered grasshoppers may become a serious plague, and are then called locusts. The long-feelered grasshoppers live singly on trees, and are usually harmless. The name locust is a source of confusion; it is applied to the short-feelered grasshoppers, though the locust family is the long-feelered group. The name is also applied to the Cicada, the "musical locust" (122:1). To avoid confusion, the name locust should be used as little as possible.

The short-feelered grasshoppers fly well. The horny upper wings are narrow, the lower fold fanwise along straight veins. The body contains air-sacs and spaces, and the animals drift along. They sometimes reach the island of Teneriffe from Africa, and have settled on ships 1200 miles out.

The most interesting structure is the hind leg (85 : 19; 95 : 1^{ii}), modified for jumping. The third and fourth parts are long to give leverage and large to accommodate the big muscles necessary to work it. The fourth part is spiny, like a runner's shoe, and prevents slipping. Each of the feet bears pads, like rubber heels, to reduce jar on landing. This hind

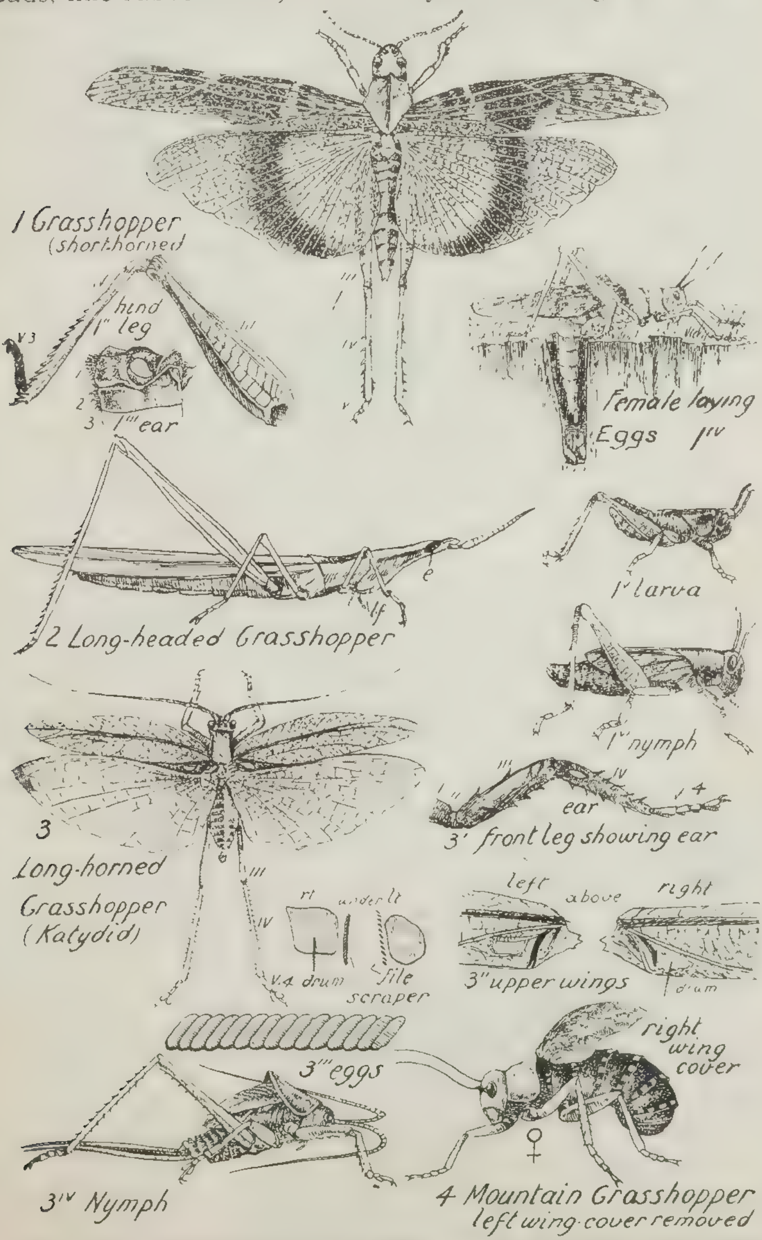


PLATE 95.—GRASSHOPPERS, LONG- AND SHORT-FEELERED.

leg is an up-to-date and efficient organ of locomotion. The long-feelered grasshopper has similar but weaker hind legs, with four foot joints instead of three as in the former.

The sound apparatus of the male short-feelered grasshopper is a row of pegs (88: 3) on the inside of the thigh of the big leg. A stiff vein in the fore-wing sets the pegs vibrating. The sound apparatus of the male long-feelered grasshopper (88: 2; 95: 3^{ii}) is a fine file on the left fore-wing set vibrating by a scraper on the right fore-wing. A "mirror" adjoining increases the sound. The note has been syllabized as "Katy did; O she did; Katy did, she did." Hence the animal is often called a katydid. Very noisy by day, some also call at night. One katydid has been called here the Great Green Gumtree Grasshopper.

The "ear" is on the first body ring of the short-feelered grasshopper (83: 20; 95: 1), and on the front shin of the long-feelered grasshoppers (95: 3^{i}).

The fore-wings (95: 3) of the harmless and interesting katydid often beautifully mimic leaves of plants, so that katydids are sometimes wrongly called "leaf-insects." Katydids can be recognized by the long hind legs, long feelers, and the long egg-placer (95: 3^{iv}) in the female.

Grasshoppers, according to Riley, the American authority, swarm about every eleven years. When they do swarm, they eat every green thing, devastating the country. Fortunately, the grasshopper is attacked by many animals—birds, insects, ichneumon flies (100: 4^{i}), and also by a fungus. Apparently the eggs wait for a favorable season, when perhaps there are few natural enemies. Possibly the eggs of the district native birds have been collected. Whatever the cause, swarms of grasshoppers suddenly appear, and must travel in search of food, causing trouble in the land. The animals, however, are an article of food valued by many African peoples. The eggs are laid (95: 1^{iv}) in holes bored in the ground, about 100 eggs being laid by each female in little egg-masses, which are covered with a jelly-like fluid; this hardens and forms a protection for the eggs. The newly-hatched young (95: 1^{v}) somewhat resemble the parents; there are no wings, and the hind legs are not yet so large in proportion. After the fourth moult, the wing traces (95: 1^{vi}) are seen; after five moults, the adult appears.

A remarkable form of the long-feelered grasshopper is the flightless female "mountain grasshopper" (95:4). If alarmed the rough wing-cover is lifted showing a brightly-colored back, which might "terrify" an enemy.

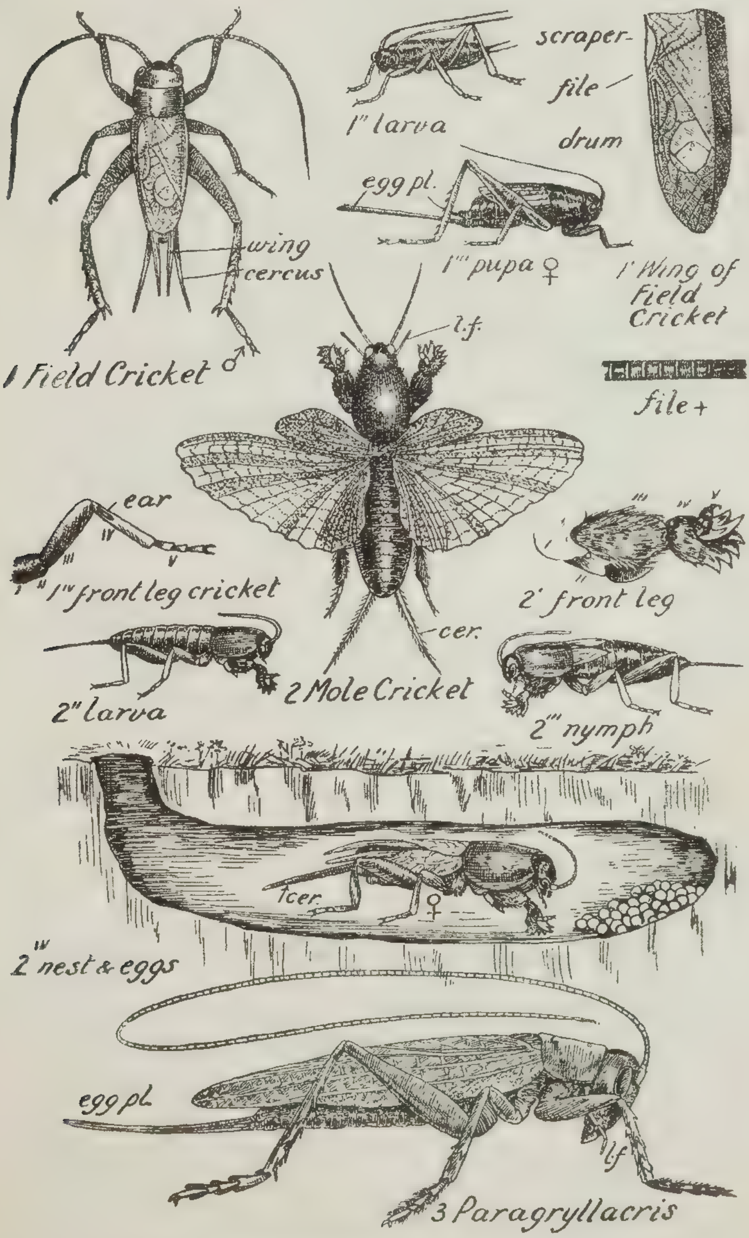


Plate 96.—PARAGRYLLACRIS AND CRICKETS.

Some remarkable, ferocious, big-jawed forms (96: 3) are met with sometimes in the family firewood. They bite savagely. One figured has no common name; it has big jaws, very long feelers, and a long egg-placer.

The mole, field, and house *CRICKETS* are included in the cricket family (*Gryllidae*). The "Cricket on the Hearth" has taken a place in literature. School children learnt about the "Silly young cricket accustomed to sing."

The burrowing mole-cricket (96: 2) is perfectly adapted to his burrowing life. His fore legs (85: 9; 96: 2^{i}) are shovels and shears. They are supported on the large well-developed fore-chest (82: 1). Though ferocious-looking, the mole-cricket is a harmless, interesting animal. The burrowing may loosen and destroy some plants, but the ploughing and burrowing must do much good. The food is disputed; possibly the animal is partly carnivorous.

The black field-cricket (96: 1) is active and difficult to capture. Like the mole-cricket, it is musical, and produces sound in the same way—by rubbing the scraper of one wing (96: 1^{i}) over the file of the other. The overlapping fore-wings are large and turned down at the side to fit the body. The under-wings fold fanwise, projecting beyond the body. The cerci (96: 1) are long and pointed. The egg-placer (96: 1^{iii}) is long also. A female field-cricket has, therefore, five long structures projecting past the body, two wings, two cerci, and egg-placer; mole-crickets have no egg-placer.

The third leg is large in each, for crickets belong to the "jumping" division of the straight-winged insects. The front leg bears the ear (96: 1^{iv}), which is easily seen in the field-cricket as a white oval on the black shin. The ear of the mole-cricket is not easily seen, but still the leg is of interest. It is modified into a most effective burrowing and cutting organ (96: 2^{i})—shovel and shears. The fourth part (shin) is flattened, and ends in four finger-like processes. The fifth part (foot) rotates over this, and has two strong projections which cut roots and other obstacles underground.

The eggs of the mole-cricket, to the number of 300 or more, are underground (96: 2^{iv}; 125: 10). The mother is said to take care of them and feed her young until the first moult, when they disperse. Other writers say the family is too large, and she kills some of them. Others again say that

the male is the guilty party. More observations are required. The animals are long-lived and larvæ (96: 2[ii]), and nymphs (96: 2[iii]) are more often seen than adults.

NERVE-WINGED INSECTS OF ORDER III. NEUROPTERA (*neuron*, a nerve).—These insects have biting mouth-parts and two pairs of membranous wings with many veins or nervures (not sensitive nerves) forming a

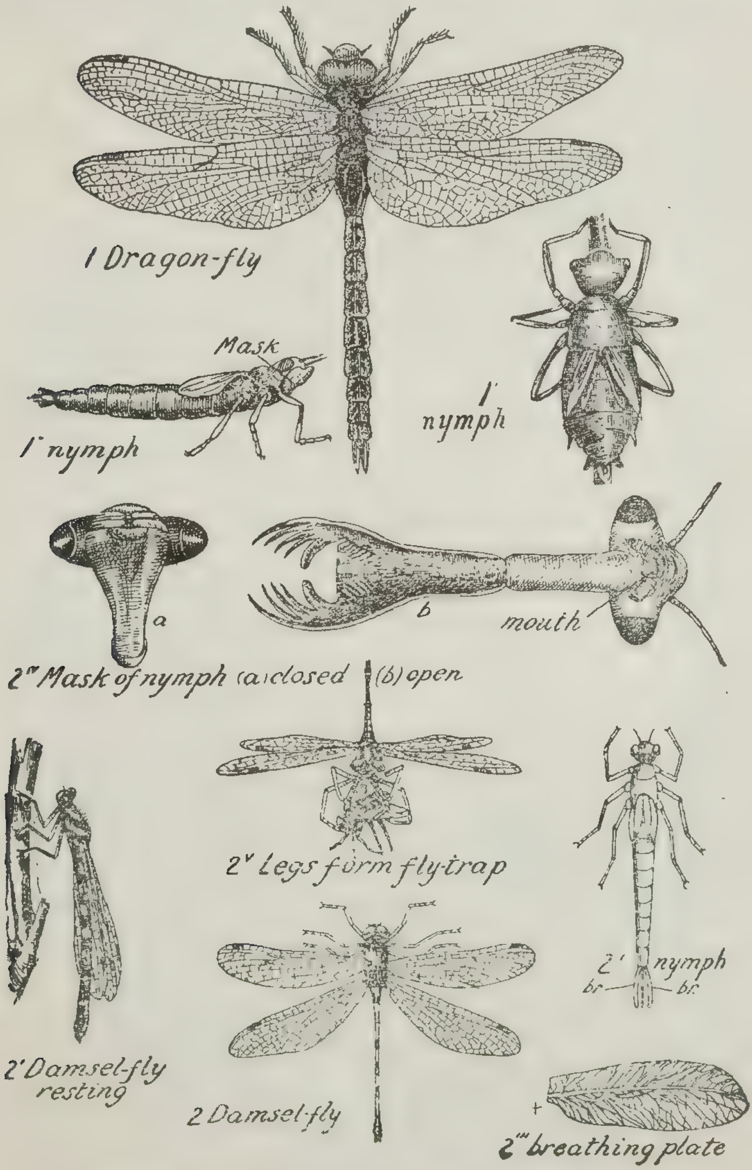


PLATE 97.—DRAGON-FLY AND DAMSEL-FLY.

minute network. Some, *e.g.*, ant-lion (99: 1) and lacewing (99: 2), during the life history undergo complete changes (larva, resting pupa, and adult); others, *e.g.*, dragon-fly (97: 1) have no resting pupal stage, but an active nymph stage. Practically, all are carnivorous, beneficial insects. Several groups have been met with in nature-study work here. These include dragon-flies (97: 1), damsel-flies (97: 2), May-flies (98: 1), stone-flies (98: 2), caddis-flies (98: 3), scorpion-flies (99: 4), Mantispa (99: 3), ant-lions (99: 1) and lacewings (99: 2). The larvæ of the first four groups are aquatic, and of the second four, terrestrial. Some authors make separate orders for the first four groups, and restrict *Neuroptera* to the second four, with some others.

DRAGON-FLIES (97: 1) have always inspired fear in the young and ignorant. Usually called horse-stingers, Devil's darning needles, or a similar name, fear of them has been traditional. However, they are not only quite harmless to us, but are valuable animals. They have no sting, and do not trouble horses or any other animals except their prey. "Mosquito-hawk" is perhaps the best name for this carnivorous tyrant of the air. It is perfectly adapted to an aërial life; its large eyes see all around it. With powerful wings it glides, darts, hovers, and even flies backwards, so that a swallow has little chance of catching one. In the male, the large compound eyes of perhaps 20,000 facets meet in mid line. The large head moves freely on a short neck. The biting jaws are strong and toothed. The feelers are greatly reduced, and probably little used. The legs project forward, forming an efficient fly-trap (97: 2^{v}). The chest segments slope up and backwards, and the wings are behind the legs (97: 2^{i}). The long slender abdomen of the male ends in two leaf-like appendages. Occasionally the biter is bitten, for a robber-fly (118: 5) carries off a dragon-fly. There are many kinds.

The life-history is interesting. The eggs are laid on water plants, the female even going into the water to place them securely. The lurking larva, the "mud-eye" of anglers, has a terrible weapon, the "mask" or jointed lower lip (97: 2^{iv}); this folds before the face, and can be thrust out to seize mosquito larvæ or other pond animals. The larva skulks in weedy, permanent pools or lagoons. It

breathes (97:1) by taking water into the rectum and expelling it. By expelling the water forcibly, it drives itself forward. After several moults, a nymph (97:1) with short wing-traces appears. After a long life of possibly two years in the dingy, weedy pool, the nymph (97:1ii) climbs a suitable plant, and the dragon-fly emerges as so beautifully described by Tennyson—

"To-day I saw the dragon-fly
Come from the well where he did lie,
An inner impulse rent the veil
Of his old husk; from head to tail
Came out clear plates of sapphire mail.
He dried his wings; like gauze they grew,
Thro' crofts and pastures wet with dew,
A living flash of light he flew."

A slender weak-winged form is called the *DAMSEL-FLY* (97:2). Its larva (90:5) is more slender, and breathes by means of three tracheal gill-plates (97:2ii) on the end of the body; these are also locomotory in function.

STONE-FLIES (98:2) are moderately large, plain-colored insects, with long feelers. The front wings are narrow; the hind wings folded in three lie along the back when at rest; there are two long tail-feelers. The adults are rarely found any distance from water. Delighting in rapids and waterfalls, they live only a few days, and do not eat in the adult stage. The minute eggs are said to be carried about by the female until they are dropped on the water. The dull-colored carnivorous larvæ (98:2ii) lurk about stones in running water. They swim little, and have constantly moving tracheal hairs (87:9) on the chest. Anglers consider stone-flies and larvæ good bait.

MAY-FLIES (98:1) are fragile insects with much-veined wings. The feelers are long, and mouth-parts are wanting. There are two or three long slender tails. Often on a summer evening May-flies engage in mazy dances about electric arc-lamps. The life-history is complicated. Sir John Lubbock observed twenty moults in the life of one individual. The numerous eggs are laid on water or under stones; some may remain six or seven months before being hatched. The vegetarian larvæ (1ii) and nymphs (1iii) lurk amongst pond weeds for one, two, or even three years.

They breathe (87: 11) by means of a "closed tracheal system," the air being spread out on a series of bladder-like plates, which are kept in motion to ensure a supply of oxygen. The nymph leaves the water; a sub-imago (98: 1^{iv}) emerges. Soon another moult reveals the full adult—the imago. The May-fly is the only insect that has this sub-imago stage. May-flies (*Ephemera*) are the type of things ephemeral and transient, and have become famous in literature. Some never see the sun: emerging at dusk, they may complete their life before morning; if mates are scarce or the weather is cold, they may live a fortnight.

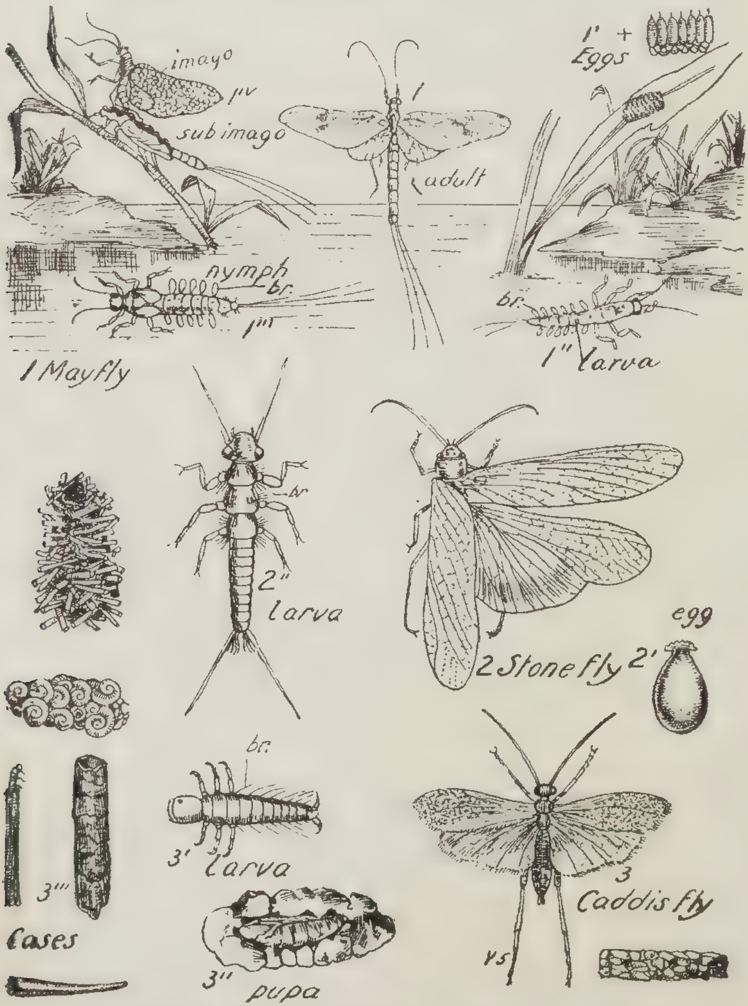


PLATE 98.—MAYFLY, STONEFLY, AND CADDISFLY.

CADDIS-FLIES (98: 3), moth-like insects with long feelers and wings meeting tentwise, are not well known; the larvæ (98: 3^{i}) "water casemoths" are favorites with students of pond life, and are used as bait by anglers. Each kind of larva uses special materials to make its case. One uses short pieces of plants built spirally (125: 7), another stones, another sand-grains, another pond-snail shells, even using live pond snails, another makes a silk case. One free-swimming larva, very common here, cuts off the end of a rush (98: 3^{iii}) and lives in the hollow in it. It is interesting to see this larva swimming with head and chest projecting

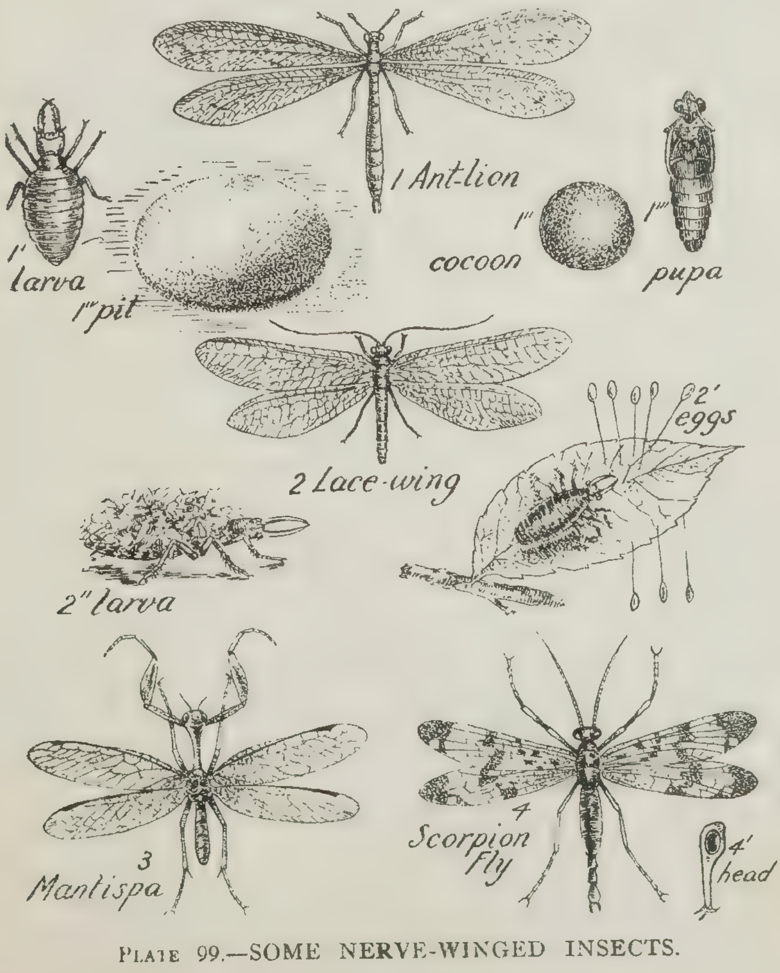


PLATE 99.—SOME NERVE-WINGED INSECTS.

The eggs are laid in a jelly-mass about pools or even under water. The soft-bodied vegetarian larvæ (98: 3^{i}) soon manufacture a case of silk and other materials. After some months, they close the case, leaving the end sieve-like, so that a current of water passes through for respiration. The animal becomes a resting pupa (98: 3^{ii}) very different from the larva, but resembling the adult. Later it leaves the case, rises to the surface, and soon the jawless adult (98: 3) emerges. Many kinds closely resemble clothes-moths. As the adults are of no economic importance, little attention has been paid to them in Australia. The larvæ are very troublesome in lily ponds. Carp, favorite pond fish, deal effectively with them.

ANT-LIONS (99: 1), the "most ingenious of insect larvæ," love sand and sun. In many sandy localities, the funnels of these remarkable animals are to be found. The writer has seen, on the sandy lower Murray, over a score to the square yard, though no part of any larva was visible. The funnels vary in size according to the age of the larvæ; some are well over an inch in diameter. Across sandy roads a long shallow groove or track may be seen; follow it and you may find an ant-lion larva travelling backwards to a new site. The track is made by the end of the abdomen. After preparing the funnel with steeply-sloping loose sides, the larva lies in wait buried at the bottom. If an insect walks into the effective trap, it slips down, is seized, and the blood is sucked from it. If the insect is large and likely to get out, the ant-lion larva throws sand at it and helps it to sink to the bottom. The blood being sucked from it, the residue is jerked out of the trap. The animal uses its head for this purpose; indeed, the whole pit is dug with the head. The name is derived from the fact that the larva preys on ants; it, of course, is not an ant. The larva spins a spherical silk cocoon incorporating grains of sand. In this it pupates. Later, the adult, somewhat resembling a dragon-fly, and having four lace wings and short clubbed feelers, emerges. The unattractive adults are mostly nocturnal.

LACEWINGS, or "golden-eyes" (99: 2), are beautiful, delicate insects. The brilliant, gauzy wings meet tentwise; some are opaque and moth-like. The brilliant eyes of one

kind are responsible for the name golden-eye. The larvæ in general somewhat resemble ant-lion larvæ; they feed on Aphids, and are called Aphis-lions. Some clothe themselves in the remains of their victims (99: 2^{ii}), and are known as "old-clothes men." Nature writers frequently describe these remarkable and valuable animals, which are more common than is usually supposed. Each egg (99: 2^{i}; 89: 7) is placed on a stiff thread. Possibly, if all were flat on the leaf, the first larva hatched would eat the other eggs. After a life valuable to the horticulturist, the larva spins a cocoon and pupates. Later, the beautiful adult emerges. It often flies about the lamp on a summer evening.

SCORPION-FLIES (99: 4) have a narrow, elongate head, long feelers, four similar shining wings, and a long turned-up abdomen, resembling somewhat a scorpion's tail. They are carnivorous, catching and holding flies with the third pair of legs. Aristotle considered them flying scorpions. The carnivorous larvæ live in rotten wood, and have eight pairs of pro-legs. There is a resting pupal stage.

MANTISPA (99: 3) bears Mantis-like front legs, and has an elongate fore-chest. It lurks amonst leaves, and occasionally comes under the notice of nature-students. The larvæ are said to be parasitic in spiders' egg-cocoons.

ORDER IV.—VEIL-WINGED INSECTS—HYMENOPTERA.

This large order includes the most highly developed of insects—ants, bees, and wasps. The termites are the only group of social insects not belonging to this important order. Hymenopterous insects are small or of moderate size. They have four membranous wings devoid of scales or hairs, and containing few cross-veins. Except in some small members, the two wings of each side are hooked together. One possible origin of the name is the joined wings (*Hymen,* the god of marriage), though it is more probable that the name is due to the veil-like wings. The biting jaws are well developed, and the second and third jaws may form a licking or sucking apparatus. Many females have a "boring" apparatus, a saw in sawflies, a long egg-placer in Ichneumon-flies, or a "stinging" apparatus in ants, bees and wasps. Hence veil-winged insects are

sometimes divided into two sub-orders: (1) Boring Hymenoptera (sawflies, gall-flies and parasitic hymenoptera), and (2) Stinging Hymenoptera (ants, wasps, and bees). The life-history has complete changes. The larvæ of the stinging insects, receiving much-needed maternal care

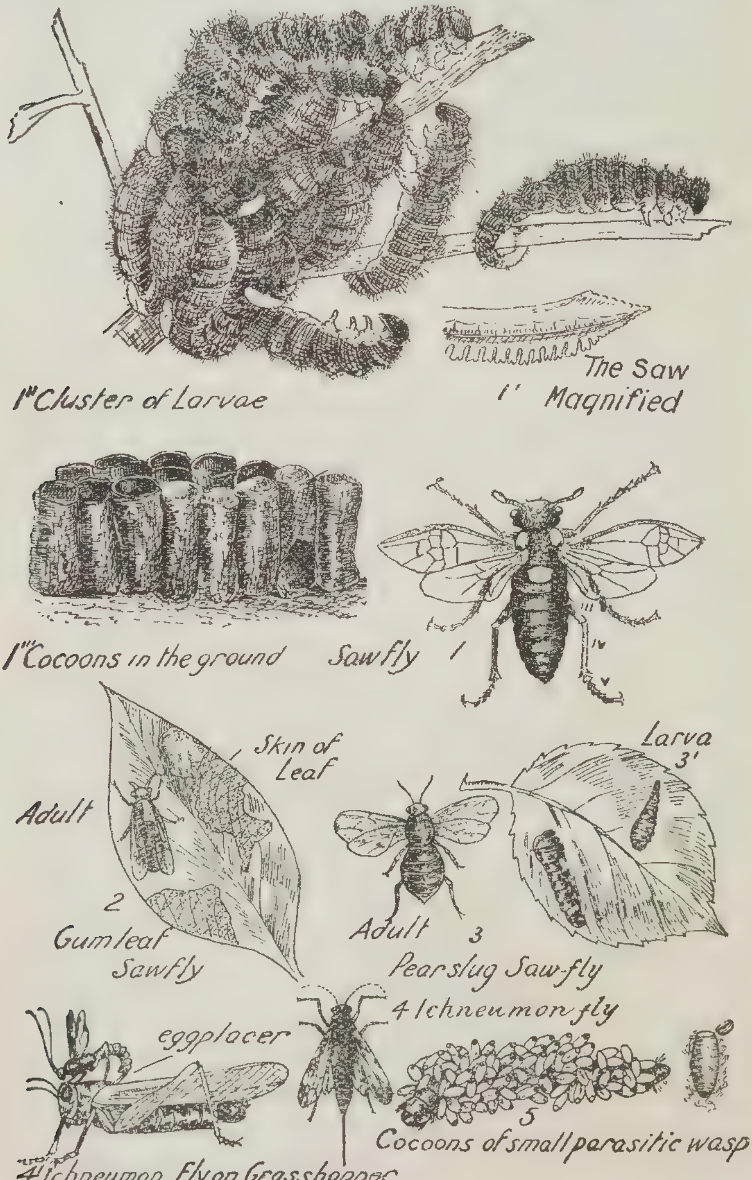


PLATE 100.—SAWFLIES AND ICHNEUMON-FLIES.

are legless, practically headless, and eyeless. The self-dependent larvæ of sawflies (100: 1[ii]) have several pairs of pro-legs. There is a resting pupal stage.

SUB-ORDER I.—BORING HYMENOPTERA.

Members of this sub-order have an egg-placer capable of boring or cutting a hole and placing an egg in it. There are three groups—sawflies, gall-flies, and the parasitic Ichneumon-flies that place the egg in a living insect or caterpillar. In the boring section of Hymenoptera, the small second joint of the leg, the trochanter, has two parts; in the stinging section, one part: so that the trochanter can be used in classifying these insects.

SAWFLIES (100: 1) have no waist, as wasps (101) and ants (102) have; the female has a saw (100: 1[i]) with which she splits open a leaf and places therein a row of eggs. The large caterpillar-like larvæ of the gum sawfly (*Perga dorsalis*) cluster (100: 1[ii]) on a gum twig in daylight. If disturbed, they wave the abdomen and secrete a strong-smelling liquid from the mouth. When full-fed, they pupate in the ground in tough silken cocoons (1[iii]). The gum-leaf sawfly (100: 2) larva eats out the spongy part of the leaf, and is covered by the skin (cuticle) of the leaf; it causes much damage to eucalypts and other trees. The soft-bodied, slimy "pear slug" (100: 3) is a sawfly larva that damages hedges and fruit trees; it eats off the green part, causing fruit trees to look as if burnt.

GALL-FLIES, mostly small, live in plant galls; many have complicated life-histories. Some members of this group do not live in galls, and many galls are not due to them; the gall-fly of the fig (45: 13) is mentioned elsewhere.

ICHNEUMON-FLIES (100: 4) are of great economic importance. There are several thousand species, each developing, as a rule, in its own particular host. The name *Ichneumonidae* is usually applied to the larger parasitic forms, and that of *Braconidae* to the smaller parasites (100: 5). The larger forms destroy grasshoppers (100: 4[i]), moth larvæ, and beetle larvæ. Many small parasitic insects lay eggs on Aphids and on the eggs of other insects. When

full-fed, many come to the surface of the host and spin silken cocoons (100: 5); later, wasp-like adults emerge.

In the second sub-order, Stinging Hymenoptera, the egg-placer is modified into a sting, usually associated with formic acid. The larva is a legless grub, fully sheltered,

PLATE 101.—WASPS.

protected, and fed on food either stored by the parent or supplied by workers. There are three main groups in this section—wasps, ants, and bees.

WASPS are grouped into true wasps and digger wasps. True wasps (101 : 4) may be recognized by the upper wings. When at rest, they fold like a fan, and are placed along the back. Digger wasps (101 : 5) have the wings flat like those of a bee; they can be distinguished from bees by the absence of pollen baskets on the hind legs.

True wasps may be social or solitary. The social wasps form colonies. Each colony is an organized community, a republic. There is no ruler, but males, females, and workers (undeveloped females) all work together, and the colony increases rapidly in individuals. The social wasps make paper-pulp (101 : 2) by chewing wood and pulping it with saliva. With the paper, they make cells, not to store food, but to contain the young, which hang by the tail, head down, in the cell. These are tended by the workers until full-fed. Then the larvæ close the cell with a silken cap and pupate. Soon an adult emerges, ready to take part in the work of the colony. One kind (*Polistes*) makes an open paper nest (101 : 2) suspended by a stalk; another (*Vespa*) makes a spherical covering of paper open at the bottom, round the seven tiers of cells suspended in a cavity often underground. This genus is not found in Australia. When winter approaches, as no food is stored, the colony, except some young females (queens), perishes. The young queens hide away in a sheltered place until spring, when each builds a nest, lays eggs, and tends the young unaided until workers emerge. The solitary true wasps generally make mud cells. One kind, *Odynerus* (101 : 4), stocks the cell with caterpillars (4^{ii}), but has not the power of stinging them and rendering them inactive as digger wasps have. So that the egg or young larva will not be crushed, the egg is suspended from the roof on a thread.

The digger wasps are all solitary, *i.e.*, they do not form colonies, though they may build several cells side by side. Still they provide well for their young by storing sufficient food with the egg, though some are said to provide further food. These wasps have solved the problem of keeping

meat fresh without the aid of refrigerating chambers. The adult, when stocking the cell, stings the spider or other animal and renders it inactive, though it lives for weeks. The larva eats the non-vital parts first, and there is no putrefying meat to pollute its home. Usually each species keeps to the one food animal; some use spiders, some caterpillars, one uses the big Cicada (122: 1). The thread-waisted wasp, a "mud-dauber" (101: 5) often makes its mud (cement) cells under a veranda or ceiling.

The flower wasps *Thynnidae* (101: 1) have the females wingless, and usually smaller than the males. One of the best known of these is the so-called "Blue-ant" (6^{ii}). It is not an ant, but the female of a wasp, *Diamma bicolor.* This iridescent purplish animal can sting severely.

The commonest, most widely distributed, longest-lived, and most interesting insect is the ANT. Man, because of his reasoning powers, ability to live in company, and work for the race instead of the individual, heads the vertebrate world: the ant, for similar reasons, is the most successful invertebrate. Ants abound from Arctic snows to scorched, withered deserts and dense tropical forests. Man aids their spread, and some foreign ants are already house-pests in Australia. The many-galleried nests are found on bare spaces, under logs, stones, pieces of bark, and even in trees. The famous "green-tree-ant," the "most pugnacious of insects," lives amongst leaves, and falls on a passer-by.

The habits of many ants are known. Sir John Lubbock kept workers alive in artificial nests for about seven years and a queen for nearly fifteen years.

The first body segment unites with the chest; the second, and sometimes the third, form distinct "nodes," and the remainder forms the abdomen proper; this double abdomen characterizes ants. It is difficult to insert a needle between the plates of the ant's armor. Ants communicate news, and recognize friends and strangers.

Males and females have two compound and three simple eyes. The poorly developed compound eyes vary from about 1,200 facets to nine, six, or even one. Some workers have no compound eyes; living much in darkness, sight is unimportant to ants.

The mouth, the chief weapon and tool, serves for digging, cutting up food, fighting, carrying prey, and for pincers, saws, and shears. The lower lip supports the tongue, which laps up liquid, rasps off food, and cleans the ant and its fellows.

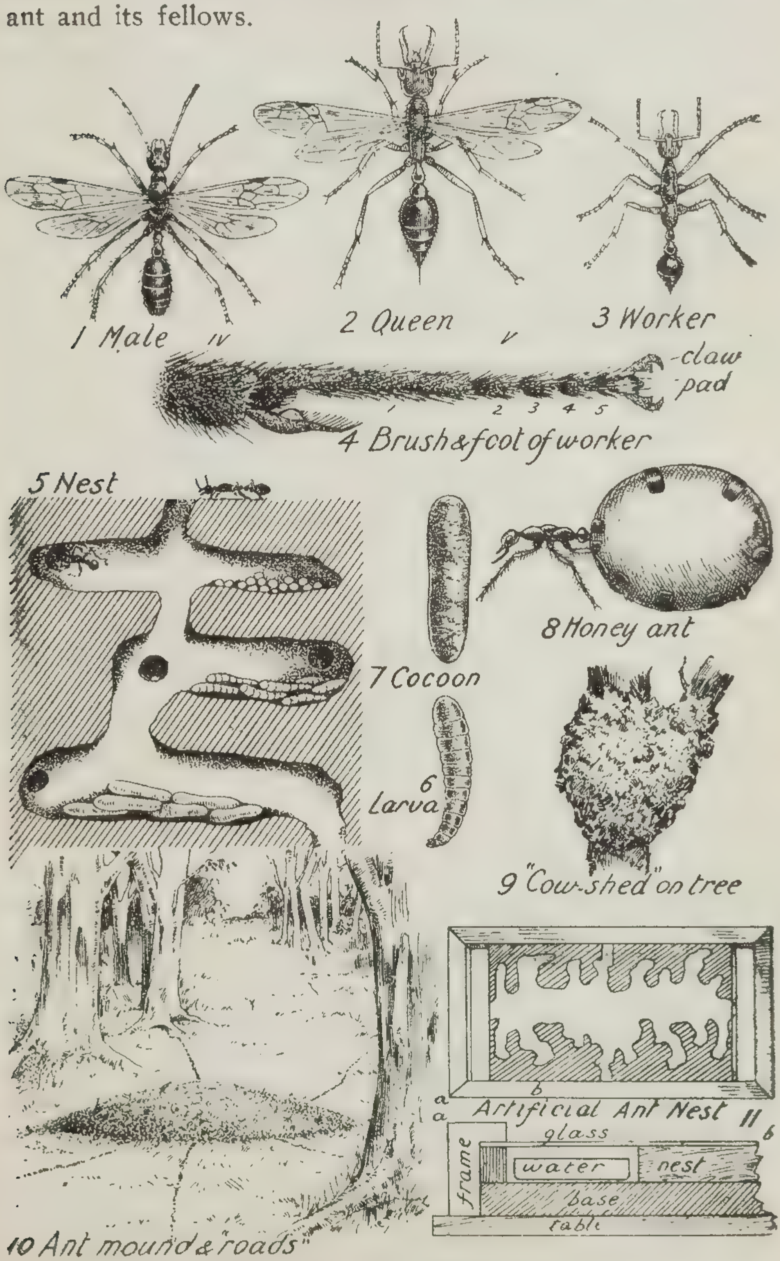


PLATE 102.—ANT STUDIES.

Each front leg bears a brush (102:4) for cleaning the feelers. The barbless sting, a modified egg-placer, injects formic acid into the puncture. Some stingless ants bite and pour formic acid on the wound. The bull-dog ant, probably the largest of ants, bites and stings fiercely. Ants display full home care. The young are fed and cleaned, and are changed frequently to the chamber suited to them. A nest reminded Sir John Lubbock of a school with children graded in "five or six classes." If a nest is disturbed, the nurses remove the minute eggs and young. The larvæ are eyeless, legless, and almost headless; when full-grown, they are covered with earth, and most spin silk cocoons in which they pupate. The cocoons are removed from the earth and brushed. When all is ready, the nurses open the cocoons, and help the young ants from the pupal skins.

The adults emerge full size. The males do not return to the nest after the marriage flight. The queen finds a suitable place, loses her wings, makes a little chamber and lays eggs; feeds the larvæ from her salivary glands; looks after her brood until they pupate; and helps them to emerge. The young ants now assume charge, and the queen becomes an egg-laying machine. The wingless workers are undeveloped females. Some nests have larger soldiers in addition to ordinary workers.

Miss Fielde, an American writer, found ants spend from 17 to 22 days as egg, 24 to 27 days as larva, 13 to 22 days as pupa; a total of from 54 to 71 days in warm weather. This period accords with the long life of ants. One ant well fed feeds others by regurgitating liquid food. Dead insects are the principal food, but any sweet or fleshy substances are eaten. Though ravenous feeders, workers have fasted nine months. Some species, flooded for days, have survived, though covered with water. Division of labor characterizes ant colonies. All ants are not equal; most are born workers; some fighters; and a few are fully-developed males and females. A large colony contains several queens, some hundreds of males, and many thousand workers.

The strength of ants is amazing. Mr. E. E. Barker has shown that the large bulldog ant has "supported 1,1000 times its own weight, equivalent to a man of twelve stone holding a weight of eighty-two tons in his teeth."

Ants are "a little people, but exceeding wise." They survive the winter, and enjoy a more successful and even life than savage man. Some marvellous habits are recorded. The keeping of "ant-cows" is well established. Ants get honey-dew from Aphids and other insects. They stand guard and protect these "cows," build sheds over them, defend them as man does his property, and change them to fresh "pastures" when necessary.

Though ants cannot make cells, they have living "honey-pots." In Central Australia, South Africa, and Mexico, "honey ants" are found. They are filled with honey until the abdomen resembles a marble. Epicures and aborigines consider these honey stores a dainty.

Ants show stages of civilization; there are hunting ants; pastoral ants, with flocks and herds; and agricultural ants that store and even plant seeds, growing their own crops, including mushrooms.

Living mostly in the ground, ants need no silken covering, except for a cocoon; they cannot spin a thread. "Green-tree-ants" fasten leaves together. Some hold leaves in position, others hold larvæ first to one edge and then to the other, while the larvæ spin threads which bind the leaves.

The use of ant-slaves, "ant-cows," and beetles that do the dirty work, is obvious, but some insect visitors are "guests"; they do nothing useful, and are tolerated or unnoticed in the ant home; others are parasites, and hide from the rightful owners, though gaining an easy living. Slave-making ant raids have been described. Over 1,500 kinds of animals are recorded from ants' nests; some of these may be pets, for ants often "play." Slave-keeping ants pay the price of parasitism. A big-jawed fighting ant (*Polyergus*) cannot eat unaided, and would starve though surrounded by food.

Some orchardists regard ants as "enemies," others as "friends." Ants live their life in the interests of the colony and good government "without guide, overseer, or ruler." They do not go out of their way to bite or sting, but do so freely if their nests are threatened.

About 2,000 different kinds of *BEES*, inhabiting most countries of the globe, are known. Solitary bees live by themselves, cuckoo bees lay eggs in other bees' cells; carpenter bees make cells in wood; mason bees use mud; small

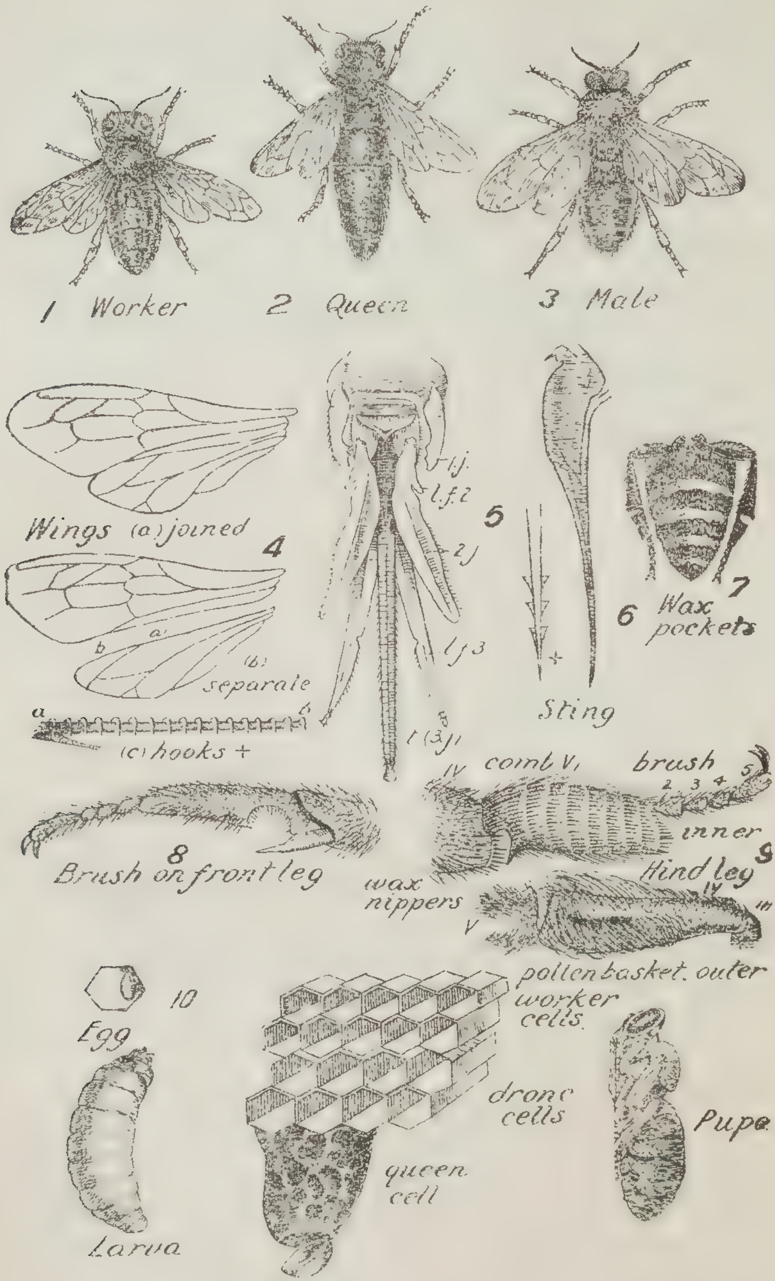


PLATE 103.—THE HIVE BEE.
5, The Tongue and Mouth Parts; 10, Life History

stingless native bees use hollow trees, as do hive bees gone wild; leaf-cutting bees cut pieces of leaves to make cells for the young; the long-tongued bumble-bees make rough cells and store food; but the hive bee is the most highly civilized and developed of all; it stores honey. In many ways its government is more completely organized than that of man. The bee colony is a republic, although the egg-producer is often referred to as the queen; but she is not a ruler. The workers control the colony and direct her actions for the most part. A successful colony usually contains one queen, several hundred males (drones), and many thousand workers, "undeveloped females." The latter tend and feed the young; gather water, nectar, and pollen; make wax and honeycomb; regulate the temperature, and do any other work. Though man has kept domestic bees for a long period, much has still to be learnt concerning their remarkable habits and government.

The structure of male, queen, and worker is different, so that there are castes, a worker caste and a reproducing caste. The worker is modified in structure to fit its life of flower-visiting and honey-gathering. The eyes are large, and contain many thousand facets. Each delicate feeler has "12,000 tactile hairs and 5,000 smell hollows." A special brush on the front legs assists in keeping the feelers

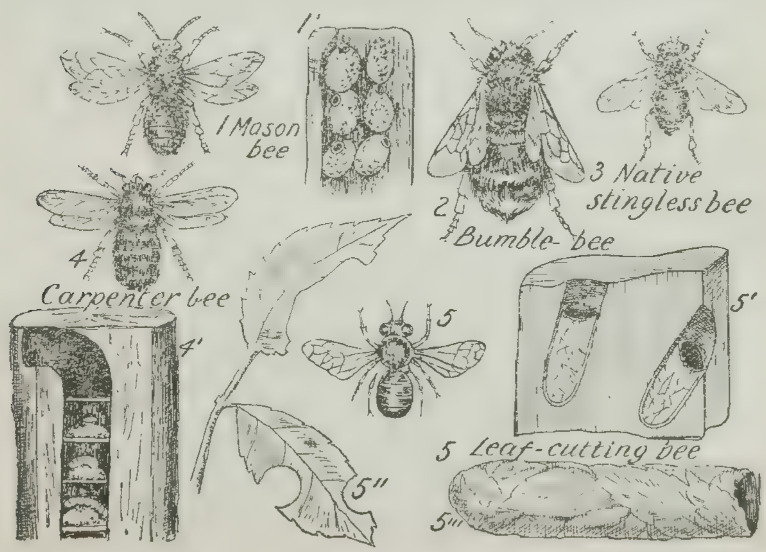


PLATE 104.—SOME WILD BEES.

clean. The mouth-parts are adapted to their work, the biting jaws are strong and are used in kneading the wax; the second and third jaws are modified into a honey-gathering "tongue," folded away when not in use.

The four wings are membranous, and are used in flight; they are not loaded with scales or hairs, but the hind wing hooks on to the front, thus enabling the worker, when loaded with honey, to fly swiftly in a "bee-line" for home.

The moderate size is suitable for flower-visiting; the tongue is long enough to reach the nectar of many flowers. The body and legs are clothed with hairs, which catch pollen; the hind foot is furnished with a brush of stiff hairs to brush the pollen from the body and legs; the end of the hind shin has a comb to get the pollen out of the brush; the "pollen basket" on the swollen hind shin then receives the pollen. Between the end of the shin and the brush is the wax-nipper. The crop stores the nectar taken from flowers. At the hive this, having been mixed with saliva, is regurgitated and stored in the honeycomb. If interfered with, the worker bee has an efficient weapon of offence in the barbed sting, which injects formic acid. The sting cannot be withdrawn, and the end of the body is usually broken away, causing the death of the worker.

The making of wax is a drain on the bee's time and energies; it is said that the bee requires to eat 20 lbs. of honey to make one pound of wax. Most apiarists extract the honey from the comb and replace the latter, which is again filled by the industrious bees.

The bee is highly intelligent, and will not waste time visiting flowers if honey can be gained more expeditiously in other ways. Bees sometimes steal from other hives, and have raided lolly-shops and sugar-mills.

The queen is longer in body, has shorter mouth-parts, and no brush on the hind legs. Her work is to lay eggs. Her sting is not barbed, and she disdains to use it except on a royal rival. The male (drone) has large eyes meeting in the mid-line, short mouth-parts, and no basket or brush; he is short-lived, being driven out before winter.

According to the needs of the hive, the workers, the democracy controlling the republic, build small cells for

the workers, larger cells for the males, and very large cells for the queens. As the queen, an egg-laying machine with atrophied brain, comes to each cell, she lays the proper egg. In worker and queen cells, she places a fertilized egg; in the drone cell, an unfertilized egg. The workers feed the young larvæ on appropriate food; the occupant of the queen cell receives royal jelly, a highly nutritious product of the salivary glands of the workers. The worker takes about 21 days to pass from egg to adult; the drones, 24 days; the queen, 17 days. The queen can bear no rival. When the young queens are showing signs of emerging, she becomes excited. Some workers protect the young queens, some inspect the locality for a swarming place, others gorge themselves with honey as they often do in case of emergency. Soon a swarm, headed by the queen, emerges. A hive, fully stocked and provided with all necessaries, is left for the young generation. Human history provides no parallel to the swarming of bees. If the swarm is not taken, it settles in a selected spot; the workers collect and store food and manufacture cells; the queen lays eggs, and all is soon in working order again. Meanwhile, a young queen has emerged, and has killed the occupants of the other queen cells, and work proceeds with the young workers in the fully-stocked home.

The queen may live several years; no male survives the winter; the workers usually die worn out before two months old; but the last autumn brood survives the winter and replenishes food stores in spring.

Ants have progressed a step further, for worker ants live several years.

ORDER V., BEETLES.—SHEATH-WINGED INSECTS—COLEOPTERA.

Beetles form the order of Sheath-winged Insects, *Coleoptera* (*Koleos*, a sheath); possibly the best known order of insects. Being easily collected and preserved, and shrinking but little, beetles are favorites with collectors. They are easily recognised, for the upper wings are usually hard sheaths, meeting on the back in a straight line. Earwigs (92:4) are the only other insects with the upper wings meeting in a straight line, and they have the long forceps

on the end of the body. The solid wing-covers, not used in flight, possibly aid in balancing the animal. Most beetles have long flying wings which fold transversely to fit under the wing-covers. Some flightless running forms have lost the under-wings, and retain the sheath-wings; sometimes, as in the case of the tortoise beetle (106:9), these grow together, effectively protecting the bearer. All beetles have biting mouth-parts, which are never modified for any other purpose. The feelers vary much in shape; they may be long or short; clubbed or tapering; comb-like, feathery, or saw-like. The feet have three joints in ladybirds (107:8); four in long-horned beetles (107:6); weevils (107: 5, 4) and leaf beetles (107:7); and five in most beetles. In one group, which includes the tortoise beetle (106:9), the joints differ in number, being four on the hind feet and five on the others. The feet are modified in swimming water beetles. There is a pad on the front leg of the male diving beetle (105:7), and an expanding swimming oar in the whirligig beetle, *Gyrinus* (105:6).

The fore-chest of beetles is always large, the mid-chest is invisible above, except for a triangle (scutellum) often seen between the bases of the wing-covers. The body (abdomen) is usually completely covered above by the wing-covers, while on the under side the first parts (coxæ) of the hind legs hide some of the body rings and cause some students to think the abdomen bears legs.

The larvæ vary; many are soft-bodied, helpless "grubs," eating roots. Some, *e.g.*, tiger beetle, are carnivorous and armed with big jaws; some, snout beetles or weevils, are maggot-like, living in their food; some, long-horned beetles, are hard-headed, wood tunnellers, eating and destroying much valuable timber. Soon a cocoon is made of whatever material is available, or the tunnel is closed at either end, and the animal pupates. The feelers, legs, and wings can be plainly seen through the thin ensheathing skin. A few, *e.g.*, ladybirds, pupate within the larval skin, which is hooked to a branch, chrysalis-like. After a short resting stage, the adults emerge full-sized. Many beetles take three or four years to develop.

The number of kinds of beetles is very great. Sharpe, *Cambridge Natural History* series, "Insects," gives 80

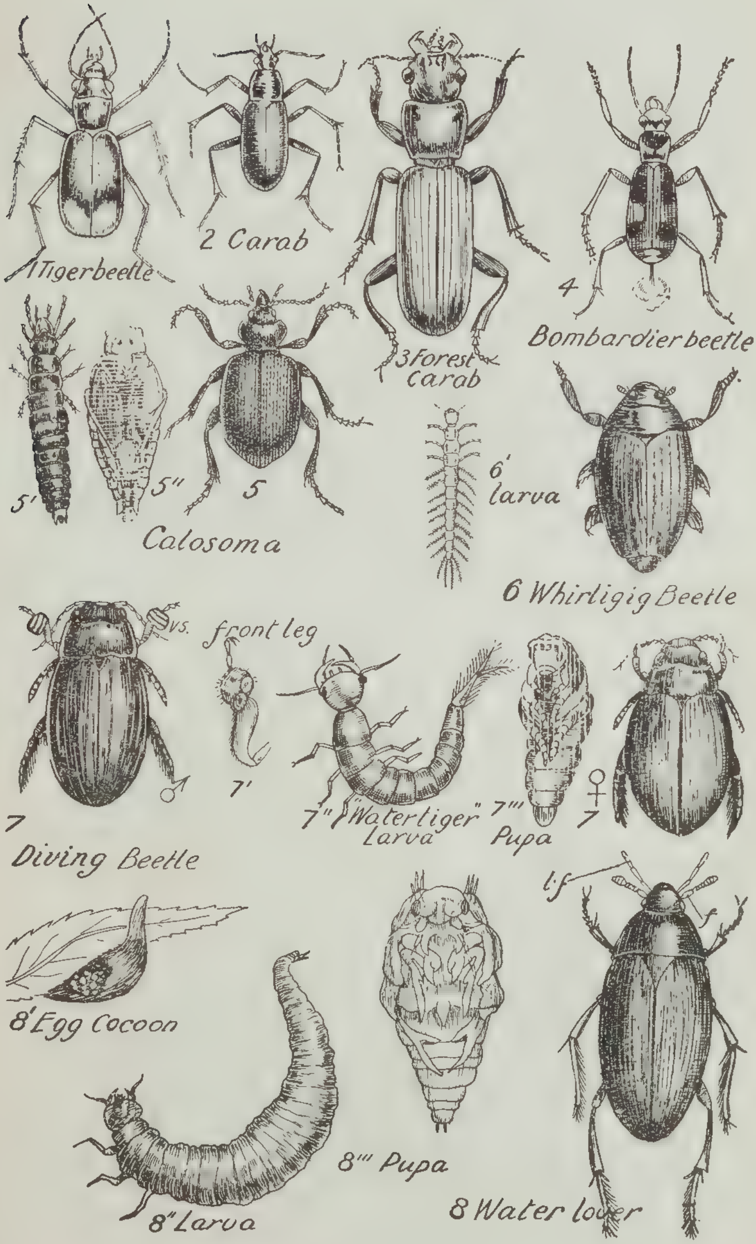


Plate 105.—SOME BEETLE STUDIES.

families, containing probably 150,000 species. Comstock estimates 80,000 kinds. Over 10,000 kinds have so far been described from Australia. Beetles are found everywhere; but, flying little, are less often seen than flies and butterflies.

The food is varied; many are valuable in checking pests, the ladybird is famous in this connexion; other beetles are serious pests, *e.g.*, the potato beetle, and many weevils, including the apple-root borer (107:4), very destructive in orchards. Some eat dung, and others eat up dead animals; some eat wood; some furniture; some feathers; and some museum specimens. One is a serious pest in cigarette factories and bond stores. Many beetles living on the ground are active runners, some live on trees, some live in water, whirligig beetles live partly on the water.

The usual defence of beetles is to simulate death; they drop from trees into the grass at the approach of danger, and often remain undetected. By placing an open umbrella under a bush, and then shaking the bush, the collector sometimes secures a good haul. The bombardier beetle (105:4) forcibly explodes, expelling a cloud of acid vapor, painful to the eyes; before the astonished pursuer recovers, the beetle has reached a place of safety. No beetle stings, though a few may bite.

TIGER BEETLES (105:1) are often beautiful; all are carnivorous and valuable. The running ground beetles (Carabs) are often flightless; all are beneficial. One of the best of them is Calosoma, a metallic green beetle, beautiful in form and color; its larvæ are voracious. It has been stated that this beetle alone renders pine woods possible in the Northern Hemisphere; it is fairly common in Australia. *BOMBARDIER BEETLES* (105:4) are found under logs and stones. Their means of defence has already been mentioned. Pond-hunters know the *WHIRLIGIG BEETLE* (105:6), which lives mainly on the surface of the water, diving when disturbed, and clinging to weeds on the bottom. It carries down a bubble of air (87:8) with it. Each of the compound eyes is divided into two —the upper half sees objects above the water, the lower half objects in the water—hence it is sometimes said to be four-eyed. The short feelers are club-shaped. The parts of the hind foot (85:6, 7) can be folded together as the foot

moves forward, and spread out as it pushes backwards. The larva (105:6) "breathes water" through hairy processes.

The *DIVING BEETLE* (105:7; 189:7) is carnivorous both as larva and adult. The male has on the front leg (85:5) an interesting clasping pad formed from three of the foot-joints. The shell is very smooth, and offers little resistance to the water. Being light, the animal floats head down, breathing at the posterior end; air is carried between the wing-covers and the back. The larva is the "water tiger" (105:7^{ii}; 87:4), a terror in an aquarium. Its grooved jaws enable it to suck while its prey is tightly gripped; holding the body in a characteristic bend, it breathes air direct into the rectum. It pupates in the soft mud.

The *SCAVENGER BEETLE* or water-lover, *Hydrophilus* (105:8) is a large beetle with the lip-feelers longer than the clubbed antennæ (feelers). The larva (8^{ii}) is carnivorous, the adult is a vegetable feeder. It flies round the street lights in summer. The eggs are laid in a silk bag, with a "mast," possibly for aerating the eggs; the bag is attached to water weeds. Soon the soft-bodied larvæ emerge, and, like the water-tiger, breathe by means of the rectum. They leave the water to pupate in a cocoon.

STAG BEETLES often have tremendous jaws, the use of which is problematical; our example is the beautiful wood-destroying golden beetle, *Lamprima* (106:1, 1^1), with fiery red or green chest and wing-covers.

ROVE BEETLES, Staphylinidae (106:2, 2^1), with short wing-covers remind one of earwigs, but there are no forceps (92:4). Several body segments are visible above. The under wings fold transversely to fit under the covers. A common British species is called the "devil's coach-horse," it bends the back and carries the tail in the air.

The *SCARABS* include the digger and chafer beetles, The cockchafer (106:5) is a troublesome pest, the larva, the "white grub" (5^1) is capable of but slight movement; it lives in the ground for a lengthy period, and destroys much grass and pasture. One kind works up soil on fine lawns, disfiguring and destroying them. The grubs pupate in a cocoon. The adult emerges, and, in some cases, waits until the following spring to begin its free life. The *"ROSE CHAFERS," Cetonidae* (106:3), are often beauti-

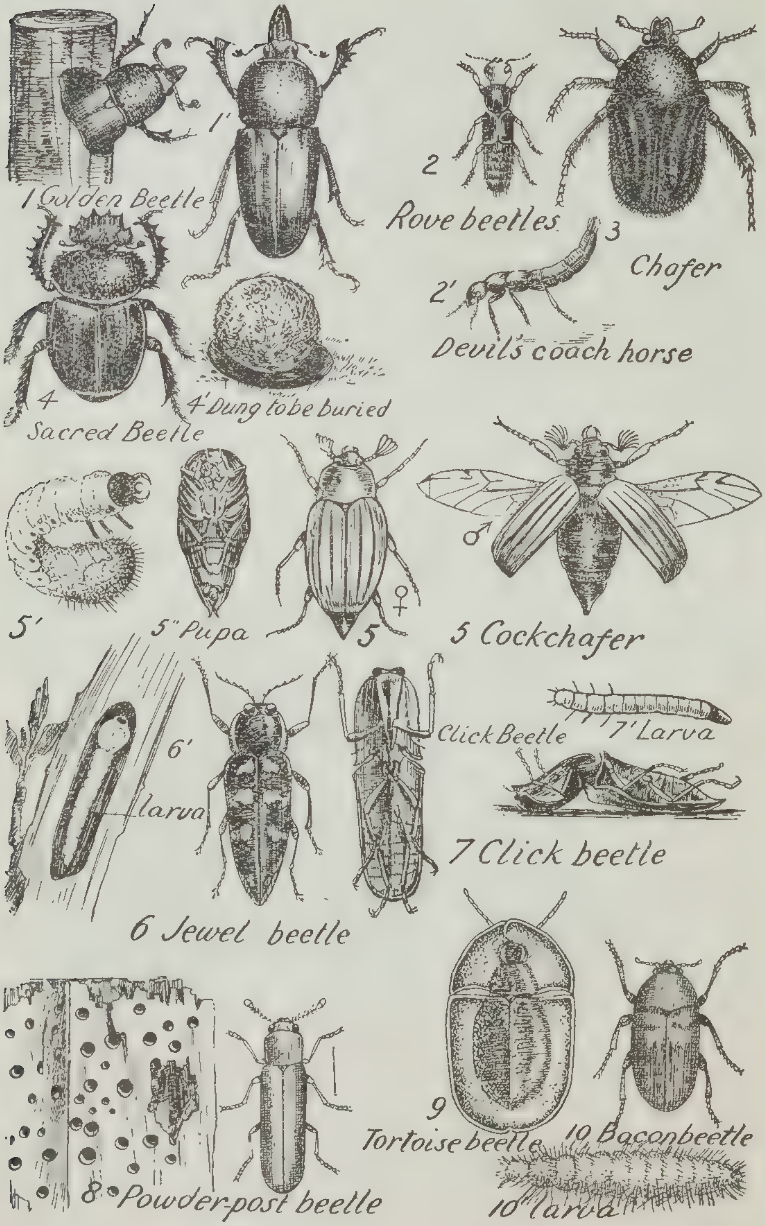


Plate 106.—SOME BEETLE STUDIES.

8 and 10, enlarged.

ful, but destructive in garden and field. The European rose chafer is not found in Victoria, but members of the family are. The name, rose chafer, is sometimes used for the family. Our example is the dusky chafer. The *SACRED BEETLE* (106: 4) of Egypt is famous. She makes a ball of dung, and, with infinite labor, buries this in a hole. She stays there until the big meal has been eaten. Later in the season, she lays eggs in a similar ball, and the larvæ have an abundant food supply. *RHINOCEROS BEETLES* (107: 3), with horns on head and chest, have similar habits; in the autumn, on sandy soil, evidences of their work may be seen in the soil turned up about horse and cow droppings. They are beneficial insects.

JEWEL BEETLES, Buprestidae (106: 6), form a large family, called also metallic wood-borers; many are very beautiful. They have a characteristic narrow wedge-shape, and usually metallic colors. The feelers are saw-like (serrate). The hard-headed larvæ (6^1), mostly wood-tunnellers, have the chest broad and flattened, the body cylindrical and soft. The adults visit flowers and enjoy the hottest sunshine. *CLICK BEETLES* (106: 7) are known to all. On a summer evening, they fly round the lamp; drop on their back; lie still a few moments; then, with a click, they jerk into the air, often to fall again. They hide under bark and stones. Their method of escape is to feign death until ready to spring; the larva is the "wire-worm" (7^1), that for "several years" damages pastures.

FURNITURE BEETLES or powder-post beetles, *Lyctus* (106: 8), are serious pests, eating the beams and girders of houses and destroying cane and wooden furniture. The pinholes and heaps of fine saw-dust are indications that immediate attention is required to save the house or furniture. *TORTOISE BEETLES* (106: 9), well ensheathed, are flightless. The wing-covers have united, and are expanded into a flat dish-like shield. The fore-chest has grown completely round the head. This beetle has four joints on the hind feet and five on the others. *BACON BEETLES, Dermestidae* (106: 10), are serious pests in museums and stores. In nature, they are valuable scavengers. The hairy larvæ are very common under bones, in rabbit skins, and under bark.

WEEVILS or snout beetles are most destructive animals. The maggot-like larvæ live in their food, and cause immense damage, eating nuts, seeds, wheat, fruits, roots, wood, leaves and flowers. Some form galls, and others are leaf-miners. The feelers are elbowed; the mouth parts are small, and situated at the end of the snout. The wing-covers are very hard. Weevils feign death, and move slowly. The female, with her snout, bores a hole in food suitable for the larva, and drops an egg into it. When full-fed, the larva spins a silken cocoon. The adults eat leaves, and can be killed by spraying with a poison mixture. The apple root-borer (107: 4), and the diamond beetle (107: 5) have been figured. Some are flightless.

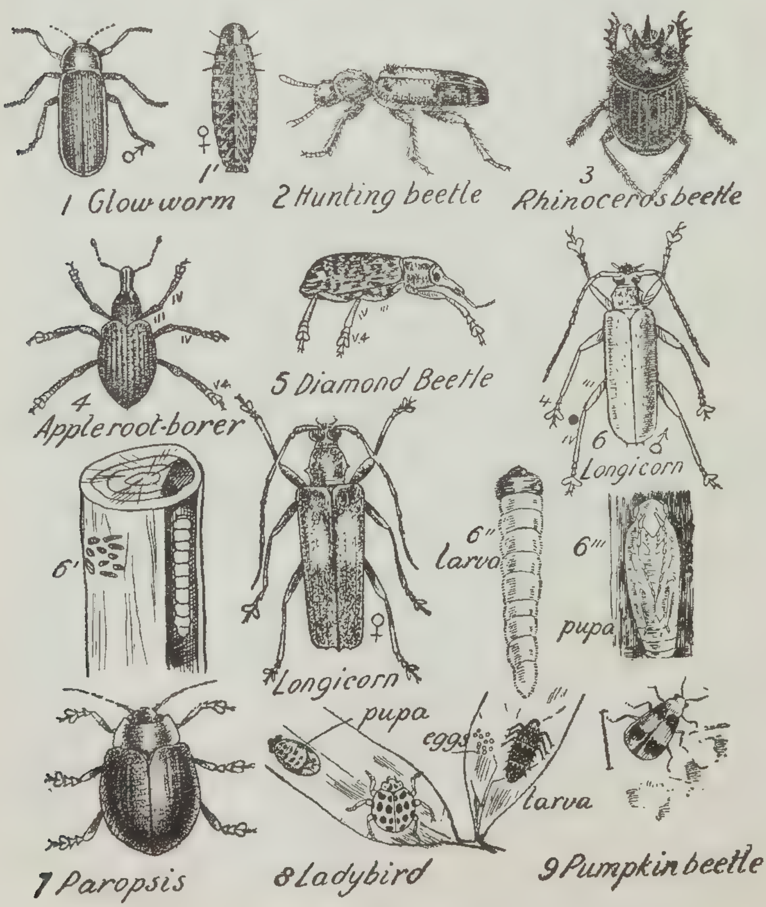


PLATE 107.—BEETLES.
7 is drawn rather large; 1, enlarged.

LONGICORNS, or long-horned beetles, form an extensive family. As they are large and beautiful in form and color, they are favorites with collectors, and are consequently well-known. The female lays the eggs under bark; the hard-headed, soft bodied larva (6^{ii}) eats its way through the hardest wood (6^{i}), and may take two or three years to reach maturity. When full-fed, the larva closes the end of the last tunnel, gets close to the bark, and pupates (6^{iii}), as most beetles do, in a soft skin, showing the parts of the adult clearly. The adults have long feelers, perhaps two or three times as long as the body. The feet have four visible joints; the third joint bears wide pads. The flying wings are well developed.

LEAF BEETLES, Chrysomelidae (107:7), also show four plain joints in the feet; they feed on leaves or other plant tissues, both as larvæ and as adults. Our example, drawn rather large, is Paropsis, a small common brown beetle suggesting a large ladybird. It is destructive to foliage. The Colorado beetle, so destructive to potatoes in the United States, belongs to this family. All are comparatively small. The *PUMPKIN BEETLE* is very destructive to plants of the melon family.

LADYBIRDS or lady-bugs (107:8), are carnivorous, rendering invaluable service in checking scales and Aphids. Comstock says, "Nothing more wonderful has been accomplished in economic entomology than the subduing in California of the cottony-cushion scale by the introduction from Australia of a lady-bug, *Vedalia,* which feeds upon it." The larvæ ("niggers") are warty-looking, and are equally valuable. Soon they fasten themselves by the tail, the pupa hangs chrysalis-like until the adult matures.

GLOW-WORMS, or fire-flies (107:1) are famous. The male is a small, soft-bodied beetle; the wing-covers are soft and the fore-chest hides the head. Most members of the family are nocturnal, and have a light-giving apparatus on the under side of the abdomen. The female of the European form is wingless.

CHECKERED HUNTING BEETLES, Cleridae (107:2), live on tree-trunks, and are beneficial insects, destroying injurious insects and larvæ; these active beetles may bite.

ORDER VI.—BUTTERFLIES AND MOTHS.

SCALE-WINGED INSECTS, LEPIDOPTERA (*Lepis*, A SCALE).

Beautiful in form and color, and easily collected and preserved, butterflies are favorites with nature-students; lepidopterists (students of moths and butterflies) are probably as numerous as students of beetles (coleopterists). This large order contains possibly over 50,000 species from the whole habitable globe, even within the Arctic Circle. Six families are butterflies, and the remainder, over 50 families, are moths. Skippers, with a skipping, jerky flight, are intermediate. Comstock divides the order into moths, or millers, skippers, and butterflies. No one character separates moths from butterflies. All are clothed in scales.

The second jaws form a suctorial proboscis (112: 2); the first are absent. No moth or butterfly bites, though the trunk of one moth can rupture the skin of an orange. When not in use, the proboscis (111: 3), which may be several inches long, is coiled up (110: 3^1). Some moths living only long enough to lay eggs, have no functional mouth-parts; all butterflies have the proboscis. The compound eyes, except in female case-moths, are well developed; the feelers are conspicuous. Butterflies (108: 1, 5) have knobbed or clubbed feelers, though the swelling may be slight. Skippers (110: 2) have hooked feelers. Butterflies constitute the group *Rhopalocera* (*rhopalon*, a club; *keras*, a horn). Moths (108: 2, 5) have usually straight or hairy feelers. Some males have fern-like (112) or comb-like feelers, the female's feelers are less hairy. One family represented in Australia (*Castniidae*) has clubbed feelers. Moths form the group *Heterocera*, "different-feelered."

Every male of the order of scale-winged insects has four wings, but a few females are wingless. The membranous wings usually bear scales, though "clear-wing moths" have scaleless wings. Moth wings are usually joined together by a spine or hairs (frenulum) on the hind wing, fitting into a fastener on the front wing. Some moths, *e.g.*, the gum emperor moth, have no frenulum, and some butterflies have a clasp joining the wings. A butterfly's upper wing overlaps the rounded hind wing, and the two work together. Usually, when resting, butterflies (108: 1^1) place the wings together vertically; moths (108: 2) do not do so.

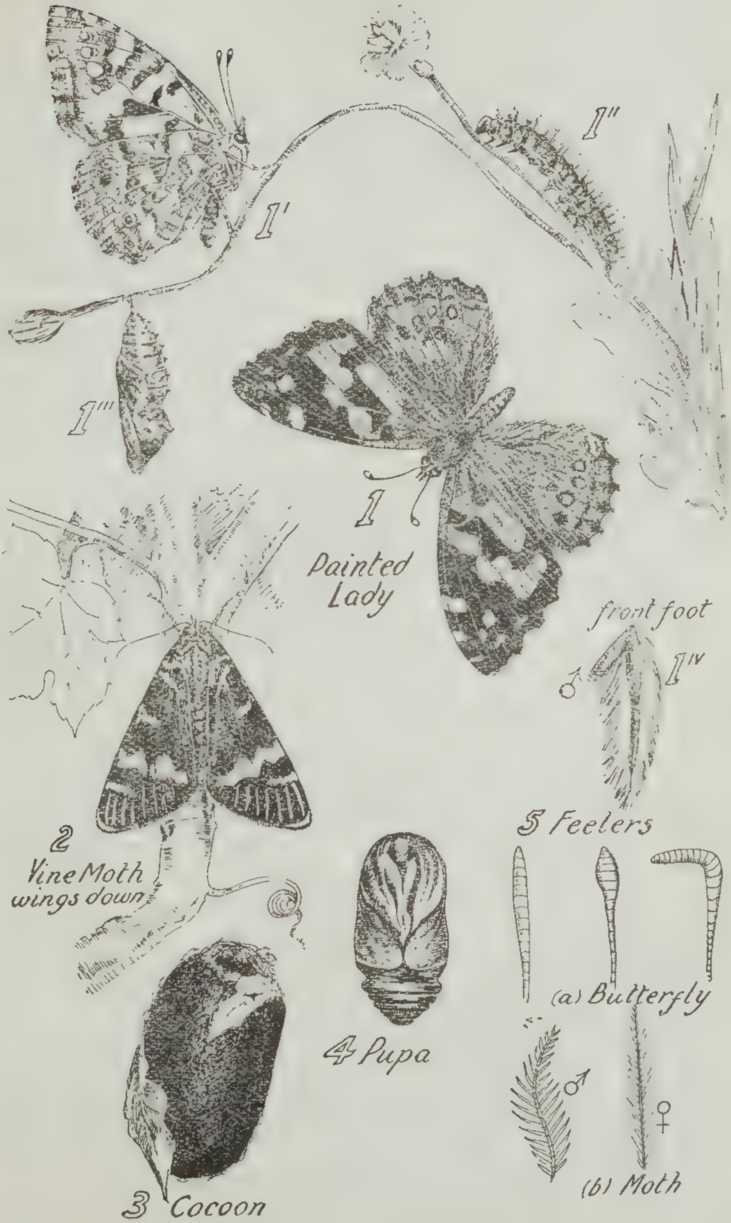


PLATE 108.—BUTTERFLY AND MOTH.
Some differences—Feelers, position of wings and pupa and chrysalis; 1IV, Front Foot of Brush-footed Butterfly.

When playing, butterflies may have the wings horizontal, exposing the bright upper side. If the insect is alarmed, the wings meet vertically, showing the protectively-colored under side. Moth-wings rest horizontally (vine moth—108: 2), or meet tentwise; (goat moth—114: 2). Locomotion is almost solely by flying. The size of the wing is not always proportional to the speed. Many butterflies float lazily on large wings, while swift hawk moths (111 : 3) have small wings. The legs, poorly developed throughout, are used for resting. In the largest family of butterflies—the *Nymphalidae* ("four-footed," or "brush-footed" butterflies), the males have flattened, hairy front feet, undivided and clawless; they are kept on the chest (108: 1). The female foot has five small joints, the usual number for lepidopterous feet.

During the life-history, complete changes are the rule. The eggs vary in shape, and are often beautifully ornamented. They are laid a few at a time on the food plant. The larvæ, on emerging, eat the egg-shells and find suitable food. Some have sixteen feet. Each of the three chest-rings bears two jointed legs. The first and second body-rings are footless, the third to the sixth bear pro-legs, the seventh and eighth are legless, and the ninth bears the claspers. The fleshy pro-legs have pads bearing hooks. They assist in climbing and walking. Some caterpillars, *e.g.*, loopers (113 : 3^{1}), larvæ of geometer moths, have two pro-legs and the two claspers. The breathing holes open on the sides, one pair on the chest and eight pairs on the body. The voracious larvæ eat plant tissues for the juices; they are wasteful feeders, and soon eat more than their own weight of food. Some few feed on plant-bugs, thus getting the plant juices indirectly, and a few that eat wood are timber-borers. Some eat stored food (flour and grain), some destroy museum specimens (feathers and furs), and certain larvæ (*e.g.*, clothes moth) eat clothing. All have biting jaws opening sideways.

When full-fed, the larva prepares to change to the winged beauty with the sucking proboscis; reconstruction is necessary. A moth larva spins a cocoon (108: 3; 115 :1) within which it prepares for its adult life. A butterfly larva (108: 1^{iii}) spins a silk pad, and hooks the end of the body into it.

The larval skin is moulted and worked upwards. The wings, legs, and feelers show for a time, but soon harden and darken. The pupa (chrysalis) hangs naked. Some butterfly larvæ spin a girdle (110: 3ii). Often the pupal stage is a long one, even nine months, though certain larvæ rest some time in the cocoon before pupating; others take a few weeks. Some butterflies, *e.g.*, the common brown, pupate amongst grass stems in a frail covering; others bind leaves together. The butterfly emerges, pumps liquid into the crumpled, moist wings, and waits for them to harden. A moth works its way out of the cocoon. Usually liquid containing acid softens it. The gum emperor moth has a knife on each shoulder to cut the threads.

The duration of life is less amongst scale-winged insects than amongst ants and termites. Some butterflies have three or more broods a year; others, (*e.g.*, wood-borers) spend three years as larvæ for a few days as adults. The "painted lady" (108: 1) may survive the winter while the "monarch" (109: 1) has lived a year—"a most unusual occurrence" for a butterfly. Females generally fly less than males, which seek their mates. The males are swifter and more slender than the sometimes clumsy females. Most moths are night-fliers, but some are day-fliers; skippers (110: 2) are day and twilight fliers.

Butterflies, to many, are an emblem of a short, joyous life. The scientific facts do not warrant this frivolous reputation, unworthy of the insect and its distribution. It is surprising to find that some butterflies are remarkably uniform throughout the world. The variety known as the "painted lady" (108: 1) is cosmopolitan, being found even within the Arctic Circle. The Australian form has one black and three blue spots on the hind wing; the typical form has black spots. Ours was, therefore, called the blue-spotted painted lady, but blue-spotted forms occur in England, and black-spotted forms here, so that they are the same species. Often, when food plants for its young are becoming scarce in autumn, it retires to rest till the spring, when, even in colder weather, it lays its eggs on the food plants (thistles), that, with the spring growth, provide sustenance for its larvæ. It is a surprise on a wild, wintry day to see a weather-beaten specimen.

PLATE 109.—BUTTERFLIES.

1, The Monarch; note scent pouches on hind wings of male (1); 2, The "Common Brown"; ♂ (Mars' arrow) sign for male; ♀ Venus's girdle) sign for female.

Britain has 68 kinds of butterflies, Victoria has about 80 kinds, though apparently the number of individuals is greater in Britain, where the "cabbage white" is a garden pest. It is an introduced pest in the United States. Let us hope it will not reach Australia!

The Monarch (109:1) of America provides one of the romances of natural history. Anderson and Spry, in their valuable "Victorian Butterflies," tell the story. Spreading from the La Plata and the Amazon into North America, even tc Arctic snows, these butterflies spread eastward to the Bermudas and reached England, France and Spain. Others spread westward across the Pacific, reaching Queensland in 1870, and Melbourne in 1872. They are spreading west through the Malayan Archipelego, and may meet the eastward migration, thus encircling and conquering the world. Fortunately, the food plant—milk weed, or cotton weed, is of no economic importance, and the spread of this fine butterfly causes no trouble to man. Apparently its natural enemies have not come with it. It is immune from attack by birds; possibly it has an objectionable taste. It lazily flaunts itself, for there is no reason to hurry or hide. The female resembles the male, which has scent pouches on the hind wings; possibly the scent renders his presence pleasant to his mate.

This insect illustrates the folly of attempting to use scientific names with non-experts. Anderson and Spry call it *Danaus erippus;* Comstock calls it *Anosia plexippus;* Rainbow calls it *Danaus (Anosia) menippe;* Froggatt calls it *"Danais menippe,"* and adds: "though it is usually figured as *Danais archippus.*"

Sharpe (Cambridge Natural History), *"Anosia erippus,* unfortunately also called *A. menippe* and *Danais archippus* or even *D. plexippus.*"

Waterhouse and Lyell, in their latest works, call it *Danaida archippus.*

What can the non-expert do when scientists differ so?

Scientific names have no place in juvenile nature-study. Fortunately, vernacular names are more stable, and we can use the American name "monarch," or the local name "wanderer." The former is preferred.

PLATE 110.—BUTTERFLIES.
1, Macleay's Swallow-tail; 2, A Skipper; 3, The Imperial White; 4, The Imperial Blue.

Following Froggatt and Waterhouse and Lyell in the classification of butterflies, we shall take six families as butterflies (including skippers) and the remainder as moths. One family is rare in Australia, being represented by but two species in the far North. The other five families are found all over the world. The first of these contains the "four-footed," or brush-footed butterflies, including many of the large common butterflies. The monarch is now practically a cosmopolitan representative of the first division of the family. Its beautiful green and gold pupa (109: 1^{iii}) hangs naked on the food plant milk weed or cotton weed grown in many school gardens. There was an irruption of these fine butterflies in Victoria in February, 1917.

The "common brown," with its four "eyes," one on each wing, has the male (as usual) smaller than the female, and differently colored. The larvæ feed on grass, and pupate in a slender "cocoon," amongst the grass stems; this is unusual for butterflies. The common brown is abundant in the summer months (November to February or March). The Admiral and the Painted Lady are also in this family.

The third family contains the blues, coppers, and hair-streaks. Our example is the imperial blue (110: 4) common on black wattles. The nocturnal slug-like larvæ live in small companies and spin a web; each full-fed larva hooks on to the web and spins a girdle. Most of the members of this family are much smaller than the imperial blue, which is figured natural size. The wings end in tails, though it is not a "Swallow Tail." These small butterflies are much prized for their beautiful iridescent metallic tints, hence the names "blues" and "coppers." Many larvæ secrete, from glands on the back, a liquid much prized by ants, which sometimes "shepherd" them.

The members of the family of *WHITES, YELLOWS* and *SULPHURS* are usually light in color, with black borders. The females are larger, and have wider borders than those of the males. Our example is the imperial white or painted Delias (110: 3), the larvæ of which live in companies of, may be, 20 or 30, on the mistletoe. The dark-colored larvæ, covered with short, fine hairs, spin a web (3^{ii}). When full-fed, they spin a girdle, moult the

PLATE 111.—BUTTERFLY AND MOTHS.
1, The Caper White; 2, The Old Lady Moth; 3, The Silver Stripe.

larval skin, and the reddish chrysalis becomes shining jet-black (110: 3ii), with a horn forked and turned down at the front end. The caper white (111: 1-1iii) is famous for its remarkable irruptions and migrations. Though its food-plant, the "native caper," is not common in Victoria, swarms, as in November, 1916, of these dainty slow-flying butterflies, suggesting giant snowflakes, appear at times.

SWALLOW TAILS.—The family includes the largest of butterflies, the bird-winged butterflies (*Ornithoptera*) of Northern Australia and New Guinea, sometimes over 6 inches across the wings. Most of the family, though not all, have a tail on the hind wing. The legs are all well developed; the feelers are distinctly clubbed. Macleay's Swallow Tail (110: 1) is the only tailed form native to Victoria. The larva can protrude a peculiar Y-shaped tentacle. The protrusion of this is usually accompanied by an unpleasant odor. Possibly this scares away natural enemies such as Ichneumon-flies. The pupæ are supported by a girdle in addition to the tail hooks. The orchard swallow-tail is large, but has no tails.

Australian *SKIPPERS* (110: 2) are grouped in the family *Hesperidae*. They skip about with a jerky flight. These moth-like insects have broad, thick heads and bodies, hooked feelers, and well-developed legs.

Skippers are mostly brown or reddish-yellow. The big-headed larvæ fasten leaves together, and hide by day.

MOTHS.

The other scale-winged insects, comprising over 50 families, are grouped as Moths, *Heterocera* (different-horned). These vary from the huge atlas moths of Northern Australia, and the owl moth of Brazil, to tiny clothes-moths, and smaller still. Over 2000 have been recorded from England, and the number from Australia is greater still. Some only of the common forms met in connection with nature-study work are mentioned here. Most moths are night-fliers; a few (*e.g.*, hawk moths) are twilight-fliers; and very few (*e.g.*, vine moth) are day-fliers. Many, *e.g.*, vine moth (113: 5), have a well-developed proboscis, and suck nectar from flowers. Others, *e.g.*, gum emperor moth, having rudimentary mouth-parts, never feed. Moths have

the wings wrapped along the body, held horizontally, or meeting tentwise above the back. The feelers are not clubbed or thickened except in the connecting-link moths (*Castniidae*), found chiefly in South America and Australia, including Victoria.

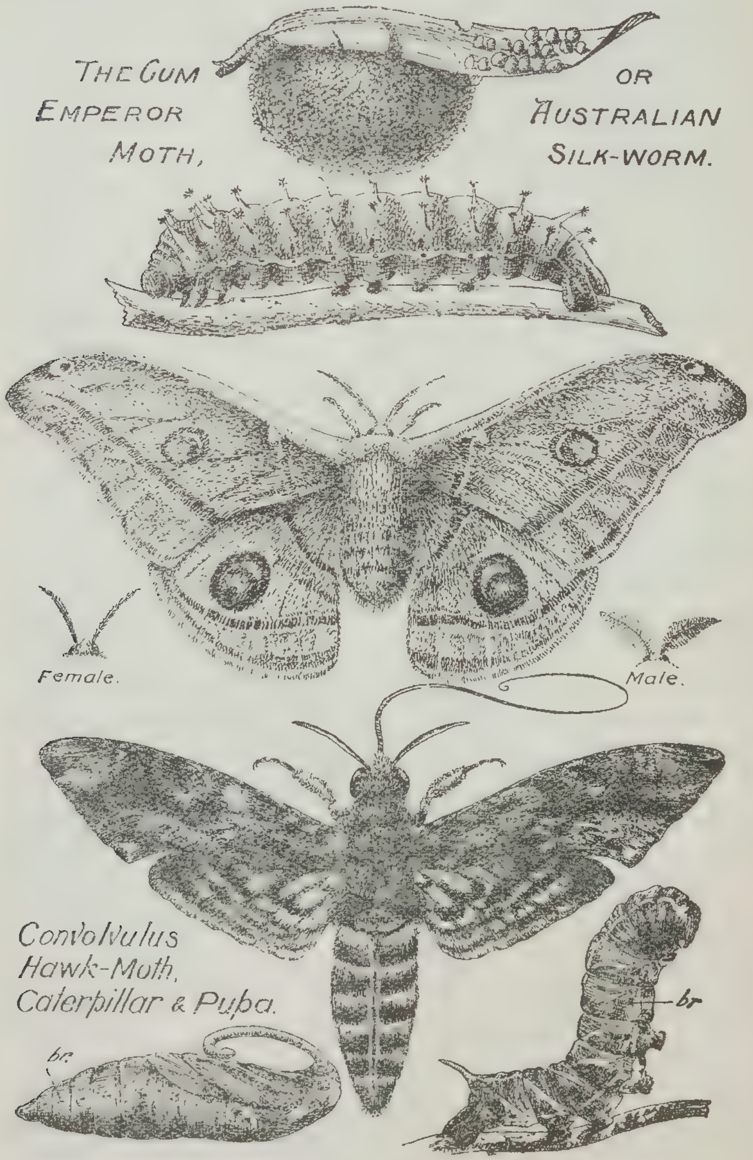


PLATE 112.—MOTHS.
Br., Breathing Hole.

The gum emperor caterpillar makes a dense silken cocoon (108: 3; 112). Some moths have flimsy cocoons. The big Colles's gum moth has a very long silk cocoon covered with the barbed hairs of the caterpillar. These hairs may cause severe irritation if the cocoon is handled.

Many moths are of great economic importance, the cut-worm (115) and army-worm (115) moths on the destructive, and the silk-worm (115:1) on the beneficial side.

The *OLD LADY, Dasypodium* (111:2), a large dark moth, is a familiar insect in Melbourne. It may often be seen on the ceiling. A large eye-spot ornaments each front wing, which, like the back wing, is crossed by many dark, wavy lines. The larvæ are grass-feeders, and the moth is harmless in a house.

The *SPHINX*, or hawk moths (111:3; 112) are rapid fliers, and are often called humming-bird moths. They hover over flowers and extract honey with a proboscis (112: 2), which may be several inches long. The silver stripe vine hawk moth, with pink under wings, was common in Victoria in the autumn of 1917. It was introduced, as was also the convolvulus hawk moth. The illustration shows the larva in the characteristic sphinx attitude.

In the same family as the true silkworm is the fine *GUM EMPEROR MOTH* (*Antherea eucalypti*) (112:1), the larvæ of which are common in places on eucalypts and the introduced pepper-trees (*Schinus molle*). It provides one of our best nature-studies. The large slow-moving caterpillars (112) will rest contentedly on a branch of the food-plant within doors, and pass through the several moults, changing color from black, blue, to green ornamented with red, blue, and yellow knobs. The caterpillars often rest with the head drawn safely back under the chest, and the knobs thrust forward to meet an enemy. The dark, pulsating line along the back is the beating heart. The breathing-holes on the sides are easily seen. Some claim that the larva is protectively-colored: the writer thinks, however, that the conspicuous larva is an example of warning coloration. It probably has an objectionable taste, and advertises the fact that it is better left alone. This is useful to the

liquid, and the animal cuts the threads with the short, knife-like projections on the shoulder. Soon the adult emerges; the wings are inflated and dried, and the beautiful moth is ready for its life-work of egg-production. The eggs are laid a few in a row on a leaf. The smaller males have fern-like feelers, and the large heavy females have hairy feelers.

One brood of caterpillars "spins up" before Christmas, and the second brood during the autumn, as late as the end of May. Moths appear in October and November, and again in the late summer. The winter is spent as a pupa (108:4). No use has yet been found for this silk. Research and experiment would probably be well repaid. The related and rarer *Antherea helena* has a somewhat similar large green larva with a pink line along each side.

TEARA moths (113: 1, 1[1]), the larvæ of which are "Processional" or "Processionary" caterpillars, are interesting. These social caterpillars live in a large silken bag suspended in a tree. The bag contains excreta, cast skins, and spines of the caterpillars. These spines cause severe irritation, and bushmen will not sleep under a tree containing a "nest." The caterpillars sometimes march in a column, head to tail.

DARALA (113:2), a moth having "woolly-bear" caterpillars, is a pest that at times damages crops and pastures. This uniformly light-fawn moth, with two black spots on each wing, is easily recognized.

The *TIGER MOTH* (113:4) has also a "woolly-bear" caterpillar which likewise is a pest. The moth's red abdomen marked with black and the spotted wings are conspicuous.

"Loopers," larvæ of *GEOMETER MOTHS* (113:3), are amongst the most interesting of insect forms. The cylindrical larvæ, with legs at each end, progress with the well-known looping action. At rest they remain stiff, and mimic a twig, so that they frequently escape notice. Occasionally, they descend by a silken thread. The delicately colored wings of the adults have often toothed edges.

PINARA, a drinker moth (113:5), comes from a cocoon that is sometimes woolly, sometimes white and hard, and sometimes even stalked and green, resembling a large acorn gall. The name refers to the long snout (the lip-feelers), which is not used for drinking. The long, fringed larva (5[1]) lies close to a twig and escapes notice; two velvety

caterpillar and good for the would-be enemy. Soon the animal becomes purplish, and looks for a place to spin its tough cocoon. The animal is now a pupa (108: 4). After a period varying greatly in length (26 days the shortest, and 400 days the longest recorded on our list), a grating, cutting noise attracts notice. The end of the cocoon is softened with

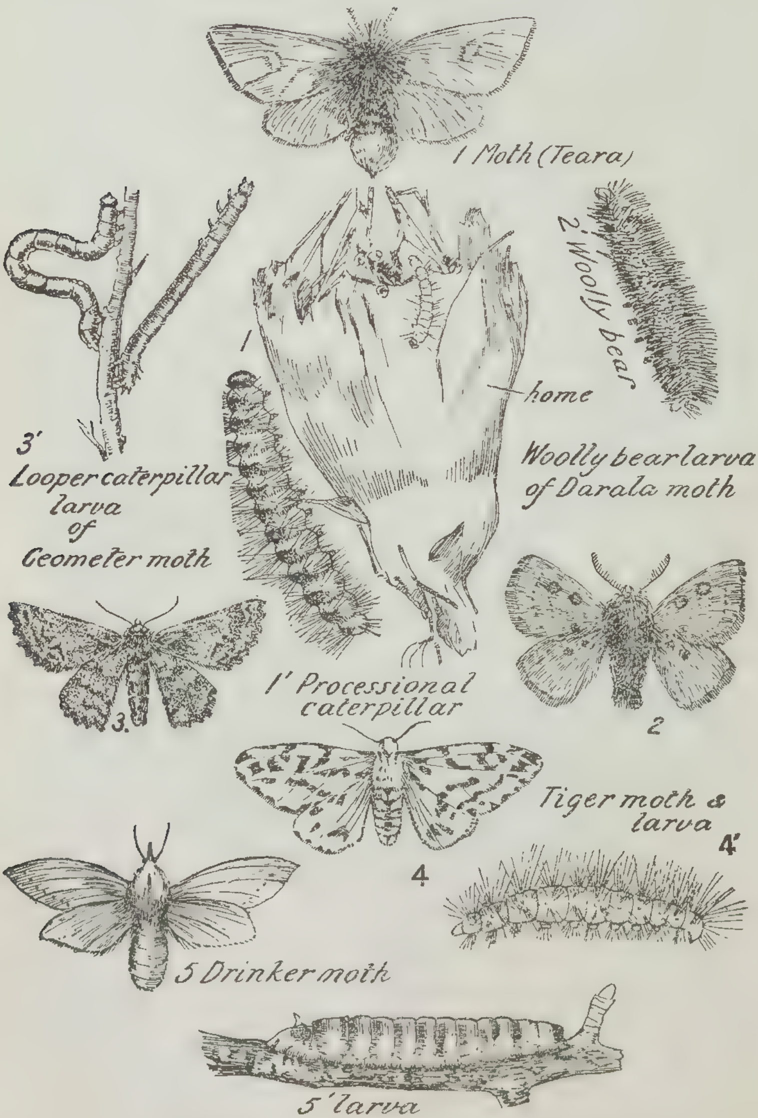


Plate 113.—SOME MOTHS
1, The Bag Shelter Moth, with Larva, the Processional Caterpillar.

black bands cross the back of the chest. One kind, having taken to the apple-tree, is an orchard pest.

The *GHOST MOTHS* fly swiftly in the dusk. The Swift moths are said not to be attracted by lights; little is known of them. Australia is rich in these forms. Some kinds, with

PLATE 114.—MOTHS.

ground-living larvæ, serve as hosts for the vegetable caterpillar, *Cordyceps,* a widely-spread fungus. The fungus spores are taken in with the food of the larva (grass roots).

Several moths are, in the larval stage, very destructive to timber. The larvæ live in tunnels eaten into stems and roots of trees. Big *MARBLED WOOD-MOTHS* emerge with each autumn rain. The finger-like pupal cases are left half-protruding from holes in the ground. A split at the front end shows where this large heavy-bodied moth has emerged. Backwardly directed teeth on each ring of the pupal skin help the animal to work out of the cocoon and up to the surface. The flesh-colored naked larvæ of *WATTLE GOAT MOTHS* (114:2) feed on wood for two or three years, and do much damage to wattle trees.

The *PAINTED APPLE MOTH* (114:3) has a wingless female. The larva bearing peculiar brushes of long hairs is very destructive to apple-trees. The wingless female lays her eggs on the outside of the flimsy cocoon. A similar insect in the United States is called the Tussock moth, while the destructive Gipsy moth of Europe is also a related species. The Painted apple-moth is a native, and is called also the wattle moth. It is a good instance of a native insect that has changed its food plant, and, by attacking introduced trees, has proved a destructive pest.

The *CUP MOTHS,* so called from the smooth cup-like cocoons, or slug moths, so called from the slug-like larvæ (114:4) are destructive at times to eucalypts. The trees, stripped of leaves, look as if a bush fire had passed through. A fresh growth of leaves may be met by a second brood of this forest pest. Tree-creepers fortunately find many cocoons in crevices of the bark, though many under raised pieces escape these birds. The stinging larvæ, sometimes called "stars," have 8 tufts of retractile stinging hairs, which, at unsuspected moments, can sting severely; though at other times it seems impossible to make them sting. The eggs are laid in a velvety sheet on the back of a leaf.

The native, day flying *"VINE MOTH"* (114:5), is a serious pest of the vineyard. McCoy says it "has totally abandoned its original food to devour the leaves of the grape-vine, never touching the former, but thriving and

multiplying beyond measure on the foliage of a totally dissimilar plant." This is puzzling when one reflects that the adult is a nectar-sucking animal, feeding largely on eucalypts, and has never *tasted the vine,* though larvæ of

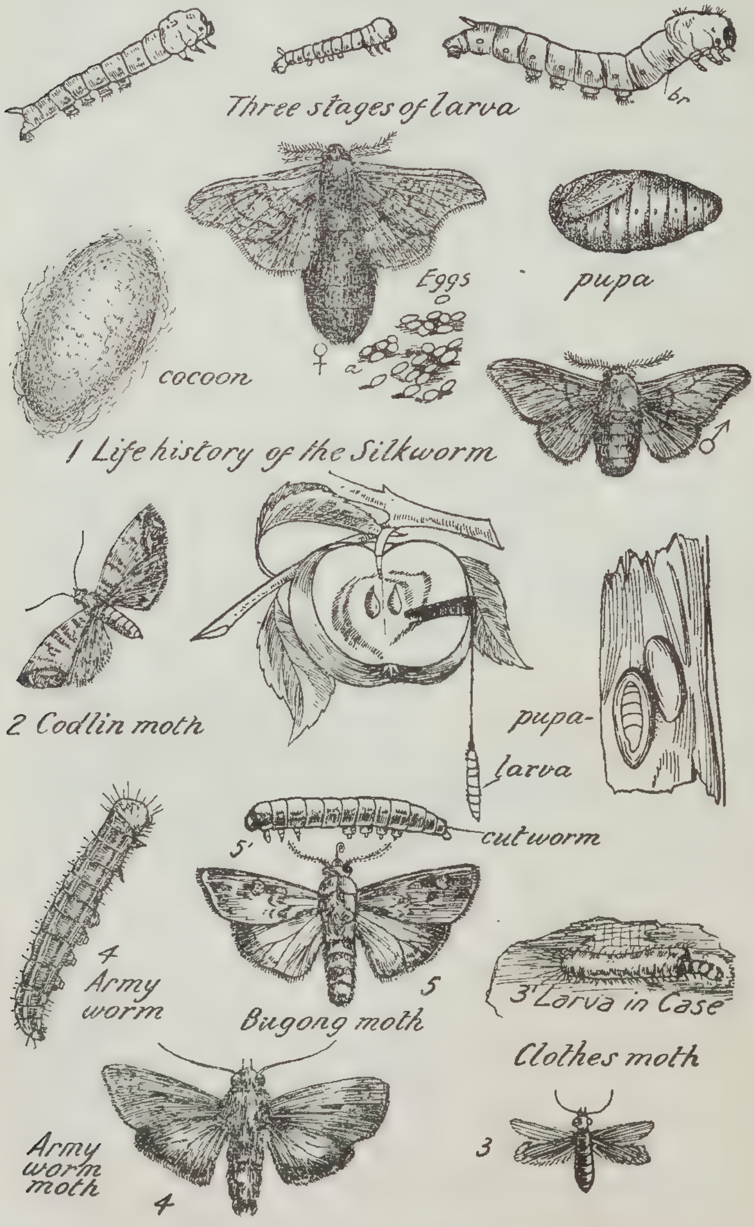


PLATE 115.—MOTHS.
5, Bogong or Bugong Moth.

most of the family feed on members of the vine family. There are usually two or three broods a year, the first moths flying about the beginning of September. The eggs are laid a few here and there on the vine. The active, greenish-yellow caterpillars marked with black and brown eat the leaves ravenously. The larva pupates in the ground in a flimsy silken and earth cocoon. Though day-fliers, the adults are typical moths (108: 2) with pointed feelers and wings held horizontally when at rest.

The *SILKWORM* (115: 1) is too well known to need much space here; though little has yet been done with it commercially in Australia. In our beautiful sunny climate, a big development seems possible. A large silkworm shows the breathing-holes plainly, the six jointed legs (real legs), the eight cushion legs (pro-legs), the claspers on the end of the body, and the beating heart. Some have two dark patches on the back, that might have served before domestication to assist the caterpillar in striking a terrifying attitude to ward off enemies. The use of the spine on the end of the body is unknown. The larva spins the well-known cocoon with a silk thread probably sometimes nearly three-quarters of a mile long. The pupa reminds one of a tightly-wrapped-up baby or doll, and has the baby name puppa or pupa (French *poupée,* a doll). The moths emerge after two or three weeks; the heavy, clumsy females live a few days to lay the eggs. Winter is spent in the egg stage.

The *BOGONG,* Bugong, or Cut-worm moth (115: 5), is the adult of a smooth, dark caterpillar, which hides by day under stones or rubbish. It bites or cuts through the stems of oat plants and wheat plants, causing serious loss. These caterpillars are often called cut-worms. Occurring in countless millions in some seasons, the moths invade houses. Possibly 40 or 50 hide under a pillow-sham. Many people fear damage indoors, but these are not clothes-moths, which are all small. The aborigines repaired annually to Mt. Bogong and gathered quantities of the moths from rock crevices. The moths were denuded of scales and wings by roasting over a fire; and the bodies, made into cakes, were much appreciated as food. The adult moth has two oblong black markings (126: 14) on each front wing, and is easily recognized. A related insect, the Army-worm moth (115: 4; 126· 17), is

a serious pest in North America as well as in Victoria. Leaf-rolling moths, whose larvæ make an interesting home by fastening leaves together, are orchard and field pests.

Though most moth larvæ live on juices of plants, the larvæ of the flour-moth destroy stored food, the bee-moth destroys honey and honeycomb, and the small clothes-moth larvæ (115: 3^{i}) destroy cloth. The larva makes a case of flannel or other material, though living in the warm medium it apparently does not need a case. Kept in captivity and fed with different-colored flannels, it is possible to have it weave a coat of many colors like that of Joseph of old. The larva pupates in the case, and the adult (115: 3) soon emerges to lay eggs and die. Adult clothes-moths do not eat.

The *CODLIN MOTH* (115: 2) is unfortunately known in the larval stage to all. The small moth, with the copper-colored patch at the end of the fore wing, is not so well known. Eggs are laid in the bottom of the flower-cup of the apple or pear when the petals are about to fall, and the developing apple grows up, and encloses the larva. When full-fed, the larva eats its way out through the side of the apple and descends to the ground. It pupates in crevices under bark and rubbish. Later, the moths emerge for a second brood. Serious damage has been caused by this pest. Arsenate of lead sprayed at the proper times has given good results. Many larvæ pupate in bands of bagging tied round the apple tree. The bands are removed and burnt.

CASEMOTHS.

Professor McCoy said: "In structure of the female and in habit, they (casemoths) are the most abnormal and singular of lepidopterous insects." Common and easily kept, casemoth larvæ are good subjects for nature-study, especially as there are many disputed and unknown points. A complete life-history of any one kind is still valuable.

The caterpillars (116: 1^{iii}), living more than one year free, need protection from weather and enemies; a case is therefore made. The stay-at-home female (116: 1^{i}) apparently succeeded best in the struggle for existence. The males (116: 1), with fern-like feelers and long narrow wings, have to find mates. Flying rapidly, they soon damage themselves; hence they are rare in collections. The female

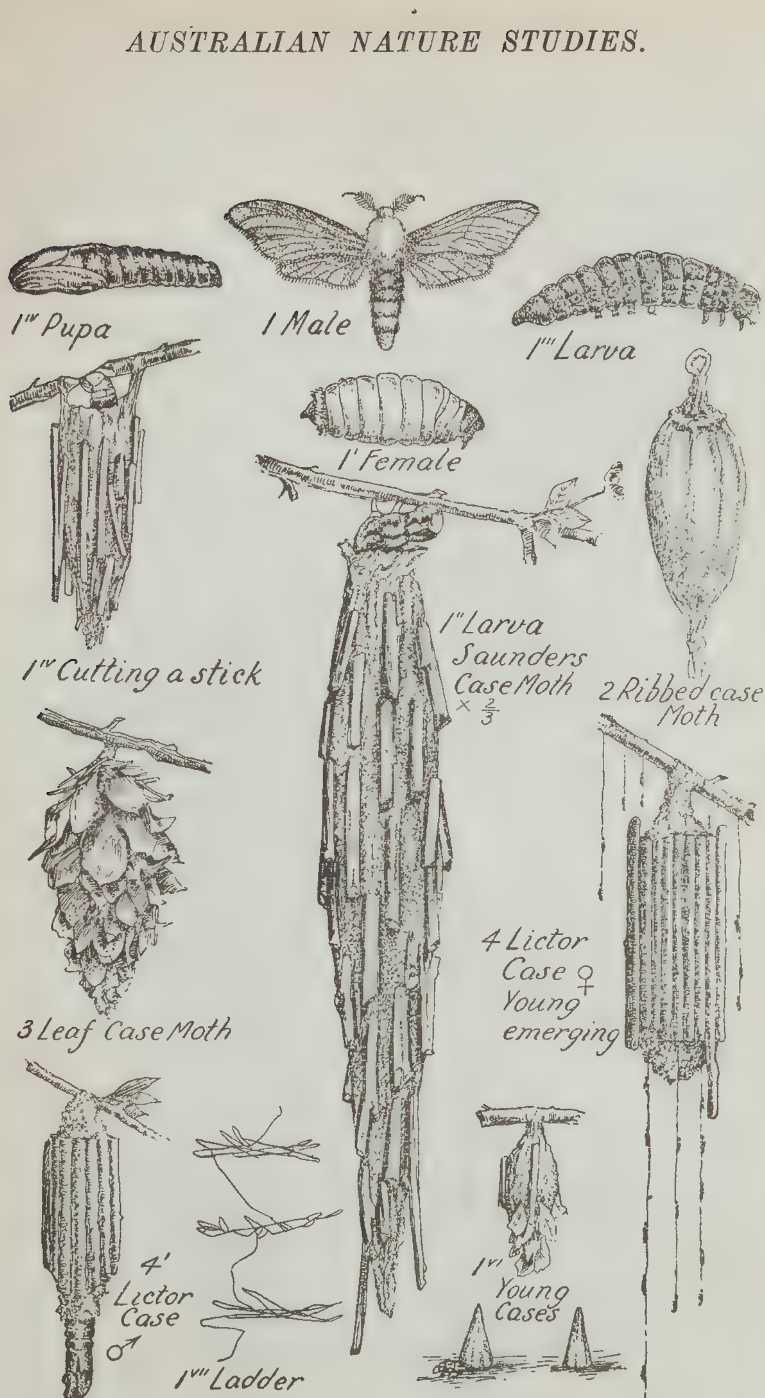


PLATE 116.—CASEMOTHS OR BAGMOTHS.

(116: 1^{i}), a worm-like egg-producer, is wingless and practically mouthless, eyeless, and legless. She wriggles up and down in the case; if she emerged, she would usually fall to the ground. The writer has had one emerge from a case on a shelf. The long-lived larva (116: 1^{iii}) even in spring may go two months without food. The larvæ take the case everywhere with them, coming far enough out to walk with the chest-legs (116: 1^{ii}). They climb walls and windows, and even cross a room, hanging from the ceiling. To assist them in climbing they make a silken "ladder" (116: 1^{vii}); a large larva usually makes several strands to a "rung." It clambers on this, and then, reaching up, makes the next rung, sticking the thread at the ends and holding the middle away from the surface with the front feet. You can watch one make a ladder on a window. The giant Saunders' case-moth (116: 1^{ii}) is represented two-thirds natural size. The cutting of a stick is interesting. A twig is chosen; the case is fastened to it at each side (116: 1^{iv}) and the animal bites through the twig. Taking the loose stick in the legs, and turning it before the mouth, it winds much silk round it; the stick is fastened across the top of the case, and the larva disappears. Soon a slit is cut in the case some distance down. The larva comes partly out through this, and winds more silk round the stick. It then fastens the top of the stick firmly into the slit; usually the lower end is free. When alarmed, the larva holds the sides of the case tightly together with the feet. The pro-legs hook into the silk of the inside of the case. Male cases are about half the size of female cases. The larva, when full-fed, suspends the case firmly, and closes the top entirely with silk. The male larva turns upside down and pupates (116: 1^{iv}). The male moth leaves the case at the bottom, the pupal skin (116: 4^{i}) protruding from the case. The female remains head up; her case serves as a larval home, a puparium, an adult home, an egg cocoon, and a tomb.

About the beginning of February, several male lictor moths have been seen. Whether the young emerge alive or eggs are laid is disputed, though eggs have been reported. However, about mid-March the many young appear (116: 4); each larva lowers itself by a thread. Within an hour, each has a case of silk, sand-grains, scraps of paper, bits of bark

An Australian Yellow-banded Parrot.

[illegible]

or leaves, or whatever is available. Her whole life through, the female never leaves this. At first, the case is carried vertically. When alarmed, the larva pulls the case, resembling a tiny candle-extinguisher, over the head. More material is added to the mouth end, until bits of leaves and sticks make the case too heavy, and it hangs down (1^{vi}). The larva has to do the spreading of the race to new places, so that it is often a great wanderer, and may occasionally be found on a busy road. The case hangs on a tree throughout the winter. In November, lictor-cases may have a dozen or more sticks, mostly of about the same length, though one or more may be longer. These are fastened at the top end, but are, at first, free at the bottom. They may be twice the length of the case. Later, the case will be found with the sticks firmly sewn down, constituting a rigid, strong cylinder; some of the original short case will be at the top, and some at the bottom (116: 4). Just how the case is spread out is not known. The cases are made of silk and whatever material is available. Some are beautiful indeed; pieces of twigs, each piece slightly longer than the preceding one, make a spiral band completing a perfect tapering case—sand-grains, grass-stems, and even string; one lictor case had several pieces of stout string that had been used to tie up sweet-pea plants on several successive days. Each day the larva cut the string and let the plants fall. There are many different kinds, the leaf casemoth (116: 3), Saunders' casemoth (116: 1^{ii}), the lictor (116: 4), or faggot casemoth, so called from the resemblance to the bundles of rods carried by the lictors or attendants, who preceded the old Roman magistrates, and the remarkable ribbed casemoth (116: 2), where the case is made of silk ribbed to keep open, are common.

Too many larvæ on a valuable plant cause trouble, but the usually small number on the ordinary tree do little harm. The silver-eye and the mistletoe-bird are said to extract the larvæ from their case.

ORDER VII.—TWO-WINGED INSECTS.

DIPTERA (*dis*, TWICE; *ptera*, WINGS).

Beetles are the most highly-developed insects in structure; bees and ants in intelligence; butterflies in ornament; and two-winged insects in the great and rapid changes made in

their life-history. Though recognised as a separate group since Aristotle's time, little is yet known about two-winged flies. The fragile adults are difficult to collect and preserve; the almost headless larvæ often live in unsavory surroundings, and few scientists have closely studied them. Because of their great importance in disease-spreading, much attention is now paid them. All have sucking mouth-parts, which, in many cases, fold away; the chest forms one mass and the five-jointed feet bear claws, and sometimes two pads. The feelers provide a means of distinguishing two sub-orders. (1) The comparatively long-feelered group, *e.g.*, mosquito and crane-fly; (2) the short-feelered group, *e.g.*, housefly. Several, *e.g.*, soldier-flies, drone-flies, and bee-flies are often mistaken for bees; they have no pollen baskets.

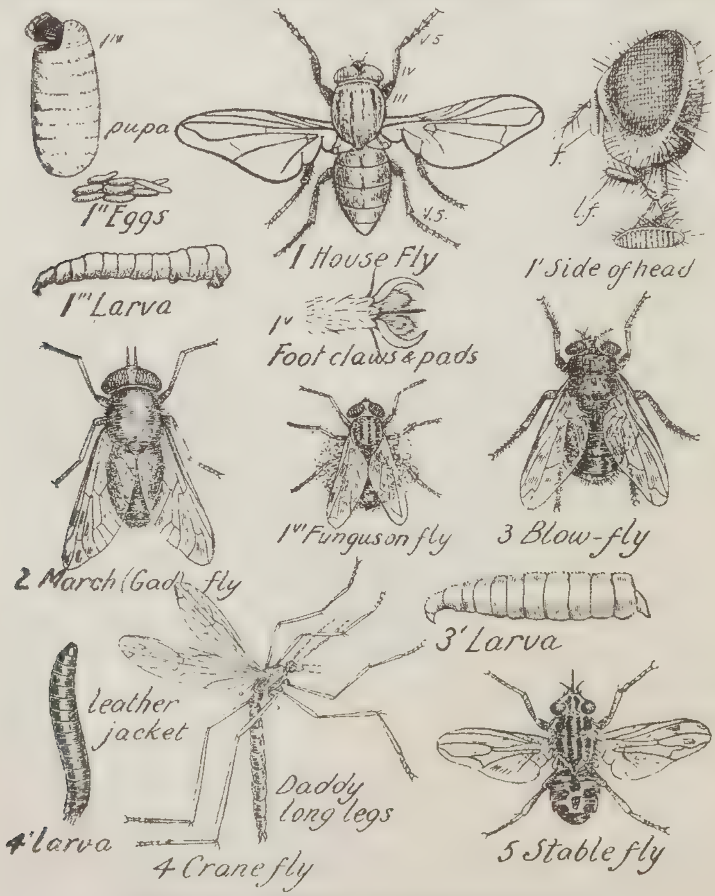


PLATE 117.—SOME TWO-WINGED FLIES.
f., feelers; l.f., lip-feelers.

All two-winged flies have complete abrupt changes in the life-history. Most lay eggs amongst the food for the young. Some larvæ, *e.g.*, mosquito larvæ, live in water. These are active to escape enemies and obtain food. Others, living in their food, pass quickly through the vegetative stage and pupate, often within the larval skin. After a few warm days, the adults emerge, full grown, and harden. No insect grows once it is winged, except the queen termite (93: 5).

No two-winged insects are social like ants, and no two-winged mother takes any care of her young; she merely lays the eggs in a suitable environment. There may be several broods a year.

Some are pests, destructive to plants and animals, *e.g.*, hessian-fly and mosquito; others are beneficial, *e.g.*, hover-flies.

The *HOUSEFLY* (117: 1) is not recommended as a pleasant study, though it is a necessary one. Living much in filth, houseflies are dangerous disease-carriers; their habits must be known in order that they may be successfully attacked. They are well adapted to their mode of life. The compound eyes are large, the short feelers bear a feathered bristle ($117: 1^{i}$). The jointed trunk has no piercing apparatus, and takes only liquid food or that dissolved by the saliva spread out by numerous channels in the flat part of the trunk. The neck allows free movement of the head. The chest is one big mass, the gauzy wings are firm and strong, the stalked bal-ancers are hidden. The hairy feet have five joints with two pads and hooks (1^{v}). The body contains five segments.

The life-history has complete changes. Eggs (1^{ii}) are laid in horse-droppings, moist filth, or rubbish. The larva (1^{iii}), living in its food, is a headless, footless maggot. Soon it pupates (91: 18) within the larval skin (1^{iv}), and the animal is reconstructed. When all is ready, the head swells, and bursts open the pupal case, and the adult emerges full size. The so-called "young flies" are adults of other species, or are starved specimens.

People say, "the flies are biting, it is going to rain"; but these are *STABLE-FLIES* (117: 5), which often come into the house before rain; no housefly can bite.

Frequenting filth for their liquid food, and in search of suitable places for the eggs, houseflies are amongst the worst disease-carriers known. Though extermination is difficult, a considerable reduction is feasible.

All food should be screened and protected from this enemy of man. Very pale flies ($117: 1^{vi}$) may sometimes be seen on a window or wall. These have been killed by a fungus related to the Irish blight, so destructive to potatoes.

BLOWFLIES (117: 3), also frequenting filth, should be suppressed. The eggs hatch soon after being laid. The blowfly is a pest of the sheep breeder in Australia. It is a scavenger. Linnæus said three flies (which increase rapidly) consume a dead horse more quickly than a lion could. The large compound eyes of the male meet in the mid-line.

The dreaded sleeping sickness is spread in Africa by the tsetse fly.

MARCH FLIES (117: 2), very common in autumn, give a painful bite. Gad-flies and horse-flies are more general names. Possibly, March flies are disease carriers. The carnivorous larvæ live in damp earth or water.

CRANE FLIES, Daddy Long-legs ($117: 4, 4^1$), are like "exaggerated mosquitoes," but do not bite. Some are large and prettily marked. The long-stalked balancers may be plainly seen. The feelers are fairly long. The extremely long legs break off easily. The larvæ, "leather jackets," live long in the ground and may be a pest to pastures, turnip and other crops. They pupate in the ground.

GNATS and midges are common names given to small two-winged insects. The plumed gnat, *Chironomus* (118: 1), is often mistaken for the male mosquito, but it is smaller than that insect. The larva is the well-known "blood-worm" (118: 1; 87: 15 a, b) common in ponds; the pupa resembles a mosquito pupa, except that the breathing horns of the latter are replaced by tufts of breathing hairs. Some of this group are the troublesome "sand-flies," whose bites are very irritating.

The *HOVER-FLY* (118: 2) is a beneficial insect. The larva preys on Aphids and forms a hard, oval chrysalis, which falls to the ground. The adult also eats Aphids, and is a valuable insect in orchard and garden. It hovers marvellously above flowers and Aphids. It is drawn too large.

The *DRONE-FLY* (118: 4) is larger and more bee-like, but it has no pollen baskets. The larva, the rat-tailed maggot (90: 20; 87: 6; 189: 4), has a telescopic breathing tube. Réaumur had some larvæ breathing in water two inches deep, and gradually increased the depth to five inches. They met this by elongating the breathing tube.

Some live in water, some in liquid or semi-liquid filth; they pupate within the tailed larval skin. They hang in the water more vertically than represented in the diagram.

ROBBER-FLIES (118: 5; 127: 11) are powerful and ferocious. They fear nothing, and even carry off a large dragon-fly impaled on the bayonet-like beak. Australia has many kinds, some large and handsome. Some are very

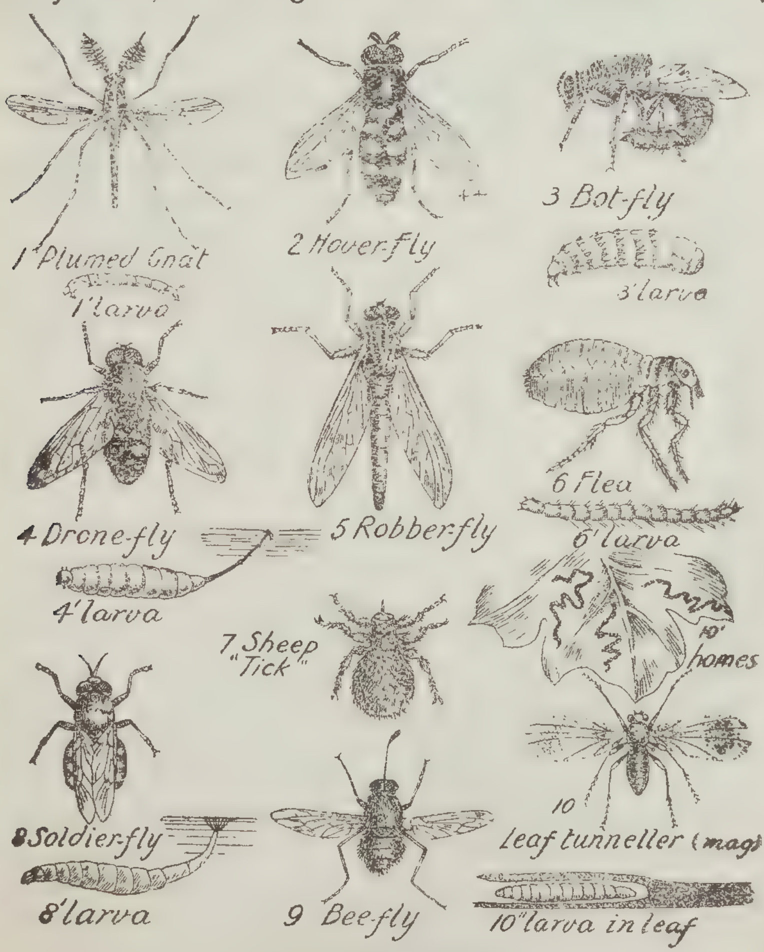


PLATE 118.—FLIES.
1, 2, 6 and 10 are Enlarged.

broad in the abdomen, others are narrow. The carnivorous larvæ live in the ground and feed on other larvæ.

The *SOLDIER-FLY* (118:8) has a broad abdomen marked with black and yellow. It is also a "bee-fly." Its larvæ (87:5; 90:22; 187:8) are common in ponds, and have a beautiful cluster of long, branched hairs on the abdomen. These hold to the water surface while the larva breathes air direct. The animal pupates in the larval skin.

The true *BEE-FLIES, Bombylidae* (118:9) are hairy, and have a long proboscis. They hover over flowers, and have remarkable powers of flight. The adults are vegetarians. The carnivorous larvæ destroy other insect larvæ. Fabre studied the life of *Anthrax,* one of the family.

The Leaf Tunneller, or *LEAF-MINER* (118:10) is an introduced two-winged insect. Many leaves of the sow-thistle and garden nasturtium show the larval tunnels. The larva pupates safe from harm in the leaf.

The female *BOT-FLY* (118:3; 126: 19), with its elongate abdomen, differs from the male. She cannot bite, eat or sting, but terrifies horses. The eggs are laid under the horse's chin, whence they fall into the feed-box or on the inside of the knee, where the horse licks them. The larvæ ($118:3^1$) hook on to the inside of the stomach, and live there for some time; they pupate in the ground.

The *"SHEEP-TICK"* or "ked" (118:7) is not a tick, which is an eight-legged animal (128:1) belonging to the same class as spider and scorpion. The "sheep-tick," a wingless dipteron, an unusual thing, was introduced with sheep. It sucks blood, and, when present in numbers, is troublesome to sheep. It resembles a stout spider.

The *FLEA, Pulex irritans* (118:6), a wingless form flattened from side to side, is sometimes classed with flies; it has tremendous jumping powers. The short proboscis enables it to pierce the skin and suck blood. It assists in the spread of bubonic plague, and possibly other diseases such as leprosy. The eggs are laid in dust in cracks or corners; the transparent larvæ ($118:6^1$) live on animal matter in the dust; and in the dust they pupate in a silken tube. Each kind of flea is said to have its own host, though many can live on other animals. Some fleas complete their life-history in a fortnight.

THE MOSQUITO.

A glass of water supplies suitable conditions and food for many mosquito larvæ to complete their life-history. Adults emerge here throughout the year. Mosquitoes are important for health reasons, and are interesting in nature-study.

The cigar-shaped eggs form a dark-brown raft (they are *not* "laid *in* a raft"). This is 1-8 inch to ¼ inch long, and, though heavier than water, floats dry, depressing the surface as a floating pin does (185: 3). If wet, the raft sinks; to wet one, however, is difficult. When pressed below, a bubble of air floats it to the surface. In warm weather, the larvæ leave the eggs the day they are laid. The eighth body segment bears the breathing-tube, having five small flaps. Open, these hold to the surface supporting the animal, which is heavier than the water; closed, they keep water from the tube. The active larva swims by wriggling, or it progresses steadily by means of the "screw-propeller," the four leaf-like flaps terminating the body. It feeds constantly at one end while breathing with the other. In six or seven warm days it is mature. The larva, with its moustache-like apparatus inducing a current of food-bearing water into the mouth, is unlike the winged, blood-sucking adult; reconstruction is necessary.

The active, lighter-than-water pupa cannot feed. It escapes danger with the aid of the two tail fins. The adult emerges from the back, which floats uppermost. The pupa has two breathing horns on the back. When below, the water cannot run into these narrow tubes (186: 13). In three warm days all is ready. The pupal skin close to the surface splits, and is pressed up and apart, the ever-contracting water-surface holding it open. The adult raises itself dry in a natural "coffer-dam." A puff of wind at this critical time might upset it, and the water surface, a death-trap for small animals, would hold it (187: 13). Soon the front feet, and, later, the middle feet are placed wide on the water. To extricate the long hind legs, the animal moves forward, and soon stands free. The feet are long and needle-like, and it stands safely on the water. At all stages —egg, larva, pupa, and adult—the mosquito uses the water-surface. Soon the wings harden, and she is ready for blood-sucking and egg-producing. She has the usual six legs, three parts, and two feelers of an insect. The head bears blood-

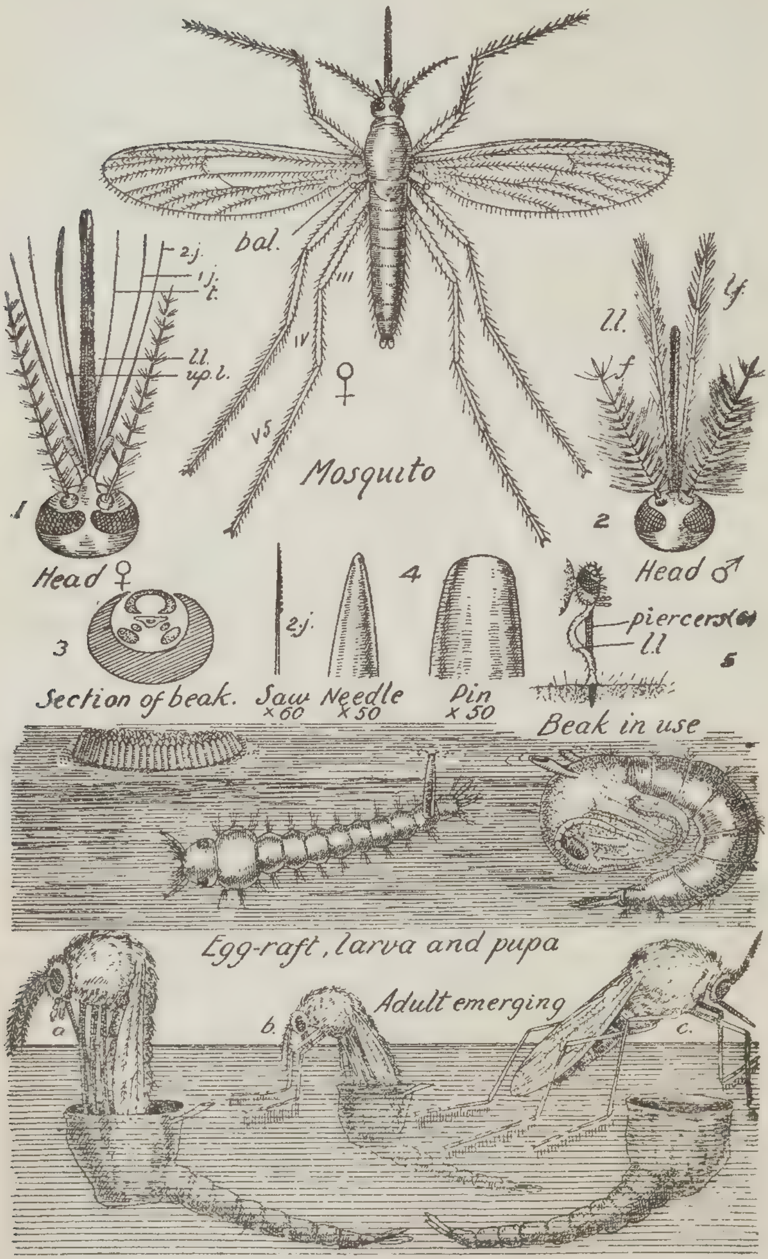


Plate 119.—THE COMMON MOSQUITO.

sucking mouth-parts, and sense-organs, eyes and feelers. The undivided chest bears six legs, two gauzy, scaly wings, and the balancers.

The "whiskered male's" long lip-feelers (palpi), hairy feelers, and short, weak beak, contrast strongly with the female's very short lip-feelers, slightly hairy feelers, and long, strong beak.

The songless male is a harmless vegetarian, living only a few days close to the breeding place. The bloodthirsty female has lived in captivity for eight months, and possibly longer in nature. She probably lays eggs several times and sucks blood many times. Certain plates connected with the breathing-holes possibly assist the wings in piping—perhaps a call for the male. Possibly the male's hairy feelers are an efficient organ of direction; facing his calling mate, the hairs vibrate equally; he has found her from a distance of 200 feet. The delicate wings serve for all the flight a mosquito takes.

Being fragile, she shelters from wind amongst vegetation, possibly on a damp lawn. Six hundred yards is probably the malarial mosquito's limit; possibly common mosquitoes travel a mile on a gentle breeze.

The blood-sucking apparatus is marvellous. The beak is a case of surgical instruments. The first jaws are long, delicate lancets, and the second, saws. Though coarse when compared with the lancets, the saws are marvellously fine when compared with the most delicate implements made by man. The illustration shows a saw magnified and a pin and a needle less highly magnified. The stout proboscis (the third jaws fused) ensheathes, protects, directs, and supports the piercers; it bends, raising the end, and the six piercers enter the victim. The long upper lip is tubular, the long flattened tongue closes the upper lip providing a passage for the blood. To prevent coagulation, the saliva runs down a fine duct in the tongue into the victim's blood. The muscular throat pumps the blood. Now, a drink for the mosquito would not be missed; but in return she may give two objectionable things—(1) poison, which affects some people much, though others seem immune to it; (2) disease-producing parasites. Mosquitoes are necessary hosts for malarial and yellow-fever parasites. Possibly mosquitoes also spread other diseases, *e.g.*, dengue-fever and filariasis. Panama, a pre-

viously deadly region, showed, under camp conditions, when the Panama Canal was being cut, a death rate of 8 per 1,000, lower than that of Melbourne, a healthy city. This diminution was achieved mainly by the drastic treatment of mosquito-breeding places by 3,000 sanitary inspectors. If mosquitoes disappear, mosquito-spread diseases also disappear. The minute malarial parasites pass into the blood with the mosquito's saliva, enter the red blood-corpuscles and undergo certain changes; they multiply rapidly, burst the corpuscles, and enter the blood. A dose of quinine kills those free in

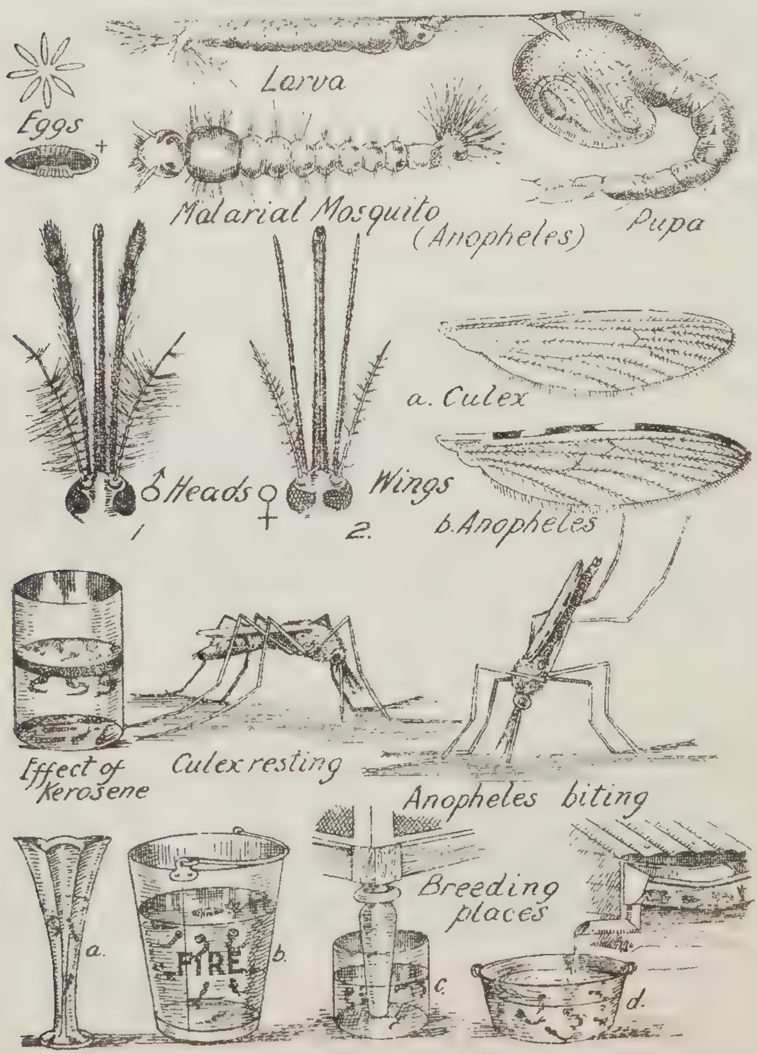


Plate 120.—MOSQUITO STUDIES.

the blood, but cannot reach those in the corpuscles. No one can "catch" malaria from a patient. If, however, a mosquito sucks blood from him, some parasites are taken up, undergo certain changes, enter the insect's salivary glands, and pass into the next person bitten.

Fortunately, mosquitoes are easily suppressed; the eggs float on water; the larvæ and pupae live in water and breathe air; the adults emerge at the surface. Kerosene floating on the water prevents larvæ and pupa from breathing. The surface film of water, so useful to the mosquito at every stage, thus provides, thanks to scientific research, a certain means of exterminating a deadly enemy. One ounce of kerosene is used for about fifteen square feet of water surface. The oil blown to one side by the wind is renewed weekly. Puddles and surface pools are filled or drained; tanks and wells are closely screened.

The number of mosquitoes breeding in a little water is amazing. The writer took 206 egg-rafts on a cold June day from a market-garden water-hole 6ft. x 4ft.; a weekly average of 63 egg-rafts for twelve consecutive weeks from two disused tanks containing three inches of water; 164 egg-rafts from a water-barrel in a town, 54 egg-rafts from a "fire" bucket, 22 rafts from a dish under a dripping tap, and 7 egg-rafts from a horse's hoof print. As an egg-raft contains from 200 to 400 eggs, these records show the enormous number of mosquitoes that may breed in unexpected places. Mosquitoes have bred in a vase on a dining table, and in jam-tins, ant-traps about cupboard legs. One pair of mosquitoes might in the year, if 18 broods developed and each female laid only once, give rise to 2×10^{39} mosquitoes. Rainwater tanks contain abundant food, and mosquitoes breed in almost any standing water except permanent ponds and lakes. For over a quarter of a century, the Biology Department, Melbourne University, has been using pond animals from the ornamental lake; not one larva has been seen there. Small fish, dragon-fly larvæ, water beetles and their larvæ, and water-bugs, especially the back-swimmer (*Notonecta*), destroy larvæ in permanent waters. Water for cattle or ornamental ponds should be stocked with such mosquito destroyers. Strange how difficult it is to convince "practical

men" that mosquitoes breed about houses and not usually in river lagoons. The following table, taken from *Health Progress and Administration in the West Indies,* by Sir Robert Boyce, F.R.S., shows where inspectors search.

Kinds of receptacle in which larvæ were found:

Antiformicas (ant-traps)	70
Barrels	64
Tubs	13
Disused tins	2
Eaves—gutters	2
Bottles	1

Many think mosquitoes tropical animals, but, in Alaska, men have been driven by mosquitoes, "to the verge of insanity and suicide." The larvæ flourish almost anywhere. They live frozen in Arctic ice the long winter through (mosquitoes winter mainly in the larval stage). In England, mosquitoes are called gnats. When, in hot weather, mosquitoes bite, they are said to be from "recently-arrived ships." Many consider malaria a tropical disease. The swampy district near Rome was a most malarious region; its climate somewhat resembles that of Melbourne. There is no climatic reason why Melbourne should be free from malaria. Until mosquitoes are infected with malarial germs from malarial patients, they cannot spread the disease. *Anopheles,* the malarial mosquito, occurs wherever sought in Victoria, including Melbourne, Wodonga (on the Murray) and the wild remote Upper Snowy River.

Anopheles usually has beak, head, and body all in one line; she "stands on her head," whereas *Culex,* the common mosquito, rests parallel to the surface with the beak at right angles. Anopheles has spotted wings. The lip-feelers are in each sex about the length of the beak: the male has hairy feelers. The eggs laid singly on water contain air-tight compartments which float them. The larvæ rest flat at the surface, and often wriggle horizontally across the pool. The pupal breathing-trumpets have a square opening instead of a long opening as in *Culex.*

The mosquito season in Victoria is the dry season, and the breeding places are often artificial. It is more difficult to treat the mosquito in a tropical climate with heavy and frequent summer rains. However, success was achieved at

Panama, Sierra Leone, and other places more difficult to treat than Australian cities.

The genus of mosquitoes, *Stegomyia,* connected with yellow-fever is found throughout Eastern Australia. There is no proof that the Victorian species can spread yellow-fever, nor is there proof that she cannot spread it. Until proved, it is better to consider that the local form may spread yellow-fever. It is hoped she will have no opportunity to do so.

So far, man has made no use of the mosquito; she has made much use of him and his standing waters. She spreads with the help of his coaches, trains, and ships.

Some people consider that everything has a use. Mosquitoes have proved most efficient agents in preventing the over populating of certain regions of the earth; possibly, this may not be considered a use.

Australians should resolve to end the mosquito pest in their neighborhood. By concerted action, this could easily be done.

ORDER VIII.—BUGS—SUCKING-BEAK INSECTS, HEMIPTERA.

Bugs—insects belonging to the order *Hemiptera* (*hemi*, half)—are better characterized by the beak than by the wings. The lengthened beak represents the upper and lower lips. The four piercers (122: 4, 5) represent the first and second pairs of jaws; fine as horse hairs, yet, being supported and directed by the beak, they pierce animal and plant tissues. All are parasites either on animals or plants. The order is divided into two sub-orders, mainly according to the character of the upper wings. The first sub-order (121) has the upper wings leathery for the inner part, and membranous and semi-transparent for the further part; hence the name *Hemiptera* (*hemi,* half; *ptera,* wings). The upper wings (121: 8) serve as covers for the folded flying wings below; they overlap and remain horizontal when at rest. Insects of the second sub-order (122: 1) have the upper wings the same throughout; often the four wings are membranous, and meet tentwise (122: 2). The first sub-order is usually called *Heteroptera* (*heteros,* different) and the second sub-order *Homoptera* (*homos,* the same).

the two water-scorpions, *Nepa* (8) and *Ranatra* (9), and the two boatmen (*Notonecta* (11) and *Corixa* (12)).

The water-scorpion (*Nepa*) and the water stick-insect (*Ranatra*) have a long breathing-tube formed of two hollow pieces. They have mantis-like seizing front legs (85:4) and the sucking beak of bugs. The larvæ and nymphs (91:17) closely resemble the adults. Both are valuable enemies of mosquito larvæ. They lurk among weeds, and move very slowly until about to seize their prey. The remarkable eggs have seven and two processes respectively: these attach the eggs to weeds.

The *GIANT BUG* (121:10) belongs to the "Fish-killers," and kills small fish. It does harm as well as good. Sometimes it may fly into the house on a summer evening, though Sharpe (Cambridge Natural History *Insects*) says the family is not represented in Australia. The writer has often had giant bugs as well as *EGG-CARRYING* bugs (121:13) with the numerous eggs cemented to the back. According to some, the female places the eggs on her own back with the egg-placer; according to others, the male carries the eggs. Froggatt records a female carrying eggs.

Following Froggatt, the name *BACK-SWIMMER* (121:11; 87:14) is used for *Notonecta,* and the name Boatman for *Corixa* (121:12). Miall classes both as Boatmen. Back-swimmer is appropriate for *Notonecta,* but *Corixa* has no other common name than Boatman. The back-swimmer swims on its back with its long oar-like legs; it is a fine animal for destroying mosquito larvæ. Corixa makes a noise, possibly by rubbing the front leg on the snout. Its eggs are laid in great quantities on reeds or bundles of sticks. The Mexicans are said to make cakes of a pleasant acid flavor from them. Both insects are common in permanent waters; both fly in search of mates.

The *POND-MEASURER* (121:4; 187:1) and *POND-SKATER* (121:3; 187:2), living *on* the water surface, are also known to pond-hunters. Both have prominent feelers, and are classed with "land bugs." The rapid short-bodied pond-skaters dart here and there on the surface of streams and pools. They stand on the surface dimpling it, as may be seen by the shadow on the sandy bottom of a shallow pool. On picnic days they attack voraciously any

Insects of the first sub-order (*Heteroptera*) are divided into "land-bugs" (121 : 1-7) and "water-bugs" (121 : 8-13). The former have long exposed feelers, the latter, small hidden feelers, folding into grooves on the head.

Many "land-bugs" are pests, parasitic on useful plants; some are carnivorous, and therefore largely beneficial. Two kinds, the pond-measurer (121 : 4) and the pond-skater (121 : 3), live on the surface of water. The "water-bugs" (hidden-feelered bugs) are all carnivorous, and are mainly beneficial insects. Several are practically cosmopolitan, and are well known to pond-hunters everywhere: these include

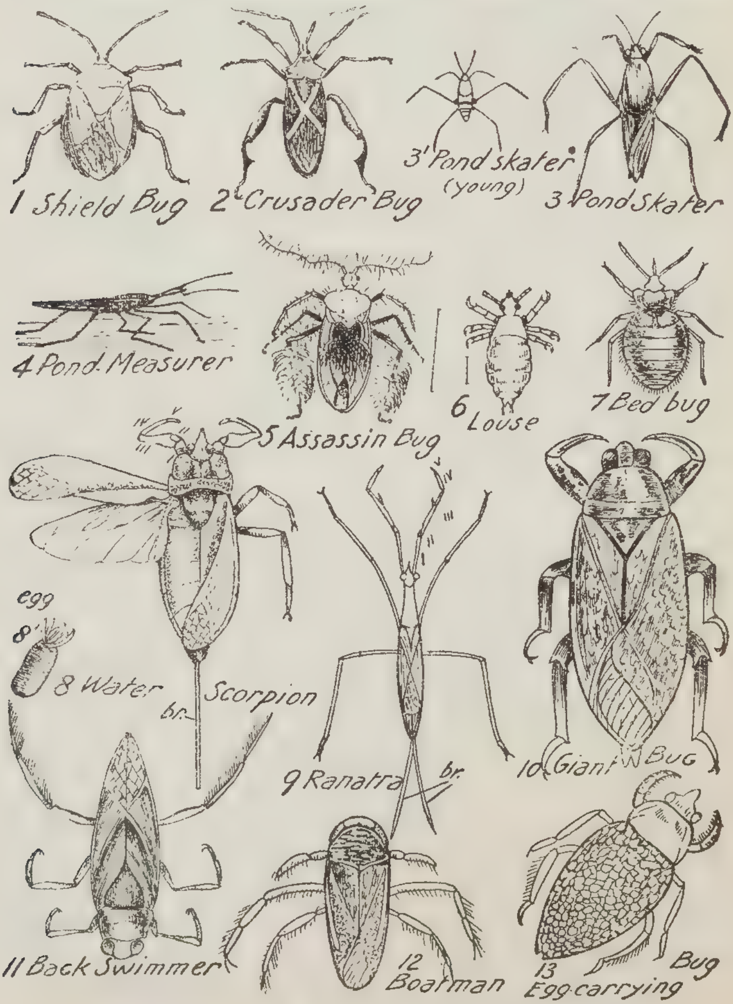


PLATE 121.—LAND BUGS AND WATER BUGS.

fat dropped from a ham sandwich at the edge of the pool. The pond measurer has a remarkable elongate head. Its velvety body cannot be wetted by water.

The *SHIELD-BUG* (121:1), with its prominent five or four jointed feelers, is very common under bark of the eucalypts. Its smell is its protection. The *CRUSADER BUG*, or Holy Bug (121:2), is a "repulsive" insect, causing damage to fruit trees. The bright red and black Soldier Bug is a common garden pest. It is extremely abundant at times, living on any garden vegetation or rubbish. It has a disagreeable odor; the bright color advertising the fact warns birds and other enemies that it is better left alone; it is a good example of "advertising coloration."

The carnivorous *ASSASSIN BUGS* (121:5) form a large widely distributed family: they are mostly beneficial. The one figured has been named the Cowboy Bug in Tasmania because of the hairy shins. It may be found occasionally under bark. The "detestable bed-bug" (121:7) is a wingless bug. Strange it does not live with savage man, but only with more or less civilized people. It is said to be devoured by cockroaches and assassin bugs, while Sharpe says a small black ant (*Monomorium*) will rid a house of the bed-bug in a few days. Related bugs live on other animals. The beak folds down into a groove.

SUCKING LICE (121:6), including the louse of the human head, are regarded as a sub-order by Froggatt. All are parasitic on animals. Modified claws enable the louse to cling to the hair of animals; a complicated sucking-beak enables it to puncture the skin and suck blood. The eggs (nits) are glued to a hair; the young resemble the parents.

BITING LICE (*Mallophaga*) form a much disputed group. Froggatt places them as a sub-order of bugs, Sharpe, amongst the *Neuroptera;* though all are wingless. They live on birds or mammals, feeding amongst the hair or feathers. They include the fowl louse.

Probably no insect is better known in literature than the *CICADA* (122). Homer, Virgil, and other classical writers mention it; the Cicada possesses, perhaps, the best sound apparatus (88:4, 4^1; 122:2, 3) amongst invertebrates. The Greeks were fond of its music, and kept Cicadas in cages, as Chinese do to-day. Latin writers and modern authors agree

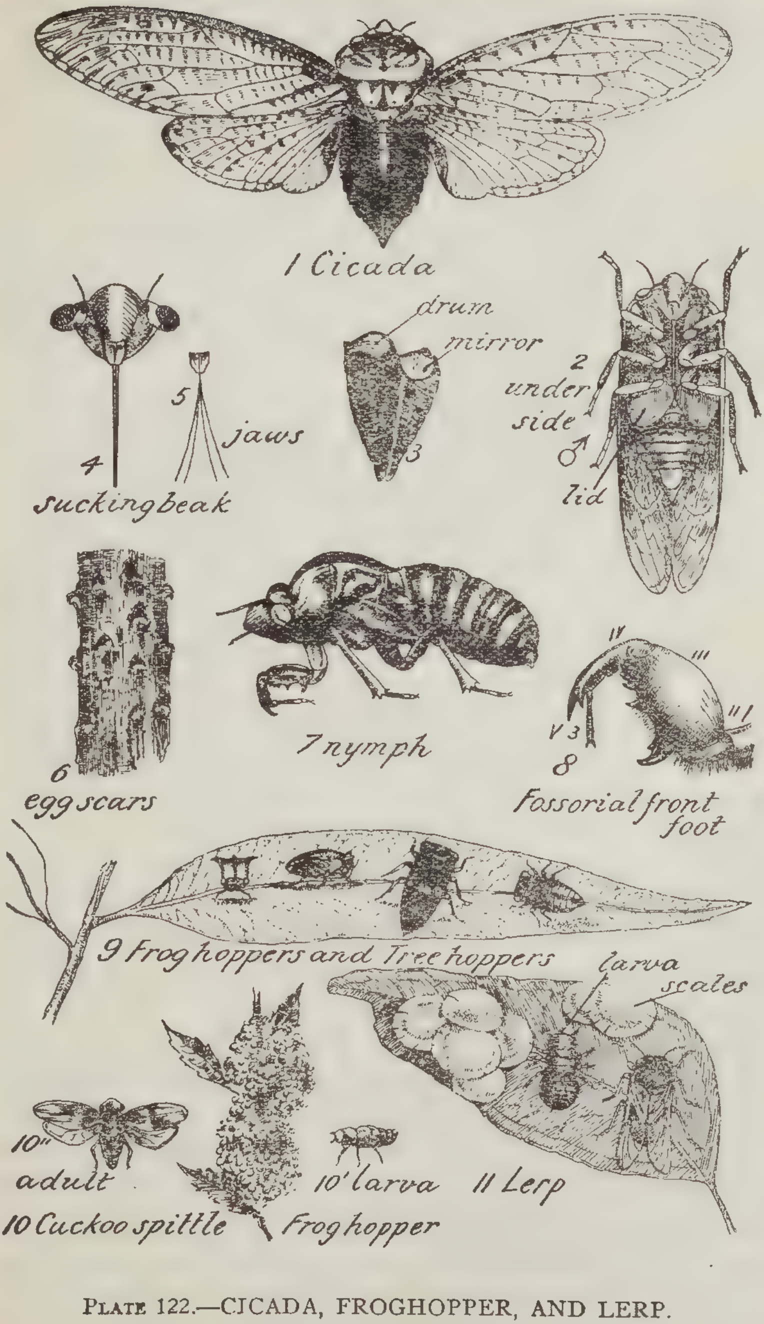


PLATE 122.—CICADA, FROGHOPPER, AND LERP.

that their notes, repeated with irritating reiteration, are unpleasant. With the Athenians, the Cicada symbolized nobility of race. They not only "addressed poems to it, struck medals bearing its image, but also, ate it." Aristotle declared it a great delicacy. The female is dumb, and one ungallant poet of Rhodes wrote:—

"Happy the Cicadas' lives,
For they all have voiceless wives."

Australian Cicadas, on a hot day, and even at night in late November and December, produce an intolerable din. The American "seventeen-year Cicada" is said to spend that time in the immature stage, to provide the adult with a few weeks above ground.

Living mostly on the "peppermint" (*Eucalyptus viminalis*) a large Cicada thrusts the beak through the young bark. The sweet, sugary sap runs out freely, the watery part evaporates, and the white "manna" falls. This sometimes happens when no Cicadas are present.

The Cicada has a broad head, a wide chest, and a large, well-ringed body. On the head (83: 10), are the compound eyes, three brilliant, simple eyes, and short, thin feelers. The long sucking-beak (122: 4, 5; 122: 2) reaches the hind legs. The Cicada is one of the largest of "sucking beak insects"—bugs. The front wings have the same structure throughout, hence the animal belongs to the sub-order *Homoptera* (*Homos*, same; *pteron*, a wing). The four strong membranous wings meet tentwise (122: 2).

The most interesting structure is the sound apparatus (122: 2, 3). If the body of a male is bent back, a chamber may be seen under the large flat lid (88: 4. 4^1). This contains a brilliant, almost transparent "mirror." Above it is a stretched membrane, the "drum," with puckers or ridges on it; to this muscles are attached. These cause the "drum" to buckle and spring back again. Just as the side of a kerosene tin makes a noise when buckled, so this produces a sound. The chambers about the "drum" serve as resonating chambers. No satisfactory reason for the noise has been given. One Cicada makes a noise like a "locomotive whistle." Since no ear has yet been discovered on a Cicada, it has been suggested that the "steam-engine whistle" may be reduced to a gentle whisper to the female.

The female has a perfect egg-placer, not visible when not in use. She scrapes grooves in a tree (122: 6), and lays several eggs in each. Soon small black young, "resembling fleas," emerge, descend to the ground, and become white, soft-bodied, six-legged larvæ. The front shins and feet are enlarged (122: 8), forming shears, and the "fossorial foot" is an effective organ. Perhaps the animal uses this to cut roots and dig underground. Possibly, the larva feeds on young roots, or on liquid from roots. After a longer or shorter period, it becomes an active nymph (122: 7). By and by the nymph climbs a convenient object. The skin cracks on top of the chest (122: 7), the head is pulled back, the chest lifted up, and the body pulled forward. Soon the animal is free from the skin, which is left complete. Cicadas occasionally appear in curious places, such as cellars, and people wonder how they get there. Their presence will be understood when it is stated that they sometimes burrow to a depth of twenty feet, and possibly life was started before the house was built. About 800 species are found in tropical and warmer temperate countries.

The practically cosmopolitan *FROG-HOPPERS* (122: 9), and leaf and tree-hoppers, often have fantastic forms. All have a sucking beak and wings meeting tentwise (122: 9). The upper wings, sometimes colored and spotted, are of the same texture throughout, so that frog-hoppers belong to the group *Homoptera* (*homos,* the same). As the name suggests, they hop or jump well. The larvæ (122: 10[1]) resemble the adults in form and mouth parts. There is a gradual change at each moult through the larval and nymph forms to the winged adult. Some larvæ, secreting honey-dew, are closely tended by ants. The larva of one kind produces the remarkable "cuckoo spittle" (122: 10), a frothy, whitish mass resembling spittle; possibly, it protects the larva, which remains at the center of the mass. Why it should be called "cuckoo" spittle is difficult to say Some American wasps drag the larva from the spittle, which reveals the animal to them more easily.

Lerp insects, *Psyllidae* (122: 11), are related forms. The active larvæ live under large scales, and are very common in places. Some of these scales, *e.g.,* "filagree scales," are

very beautiful; some are sweet and pleasant to the taste, and it is said the Tasmanian aborigines were fond of them.

Aphids, often called blight, are common on rosebuds; some are walking, others are at rest. The black eyes, two long feelers, six legs, and the two "honey tubes," are easily seen. A few have very long membranous wings, which meet tentwise (123: 1[i]). Aphids extract the sap with a sucking-beak (123: 1[iii]). Such insects, in Australia, are called "bugs." In America any small animals, especially insects, are "bugs." Aphids are also called "plant lice" and

PLATE 123.—APHIS, SCALE INSECTS, AND THRIPS.

"green flies," though they are not flies, and many are brown. Aphids are important economically, and interesting scientifically. In warm weather, when growth is vigorous, the animal constantly feeds, and produces live young from twelve to fifteen at a time. In about a fortnight, the young are mature, and reproduce young also.

Professor Forbes calculated that the progeny of one Aphis, if nothing happened to kill any, might result in three and a half trillions emerging from the eggs next season. Since each is about 1½ millimetres long, these touching head to tail would form a procession about 7,800,000 miles long, reaching about 1000 times round the equator.

Professor Huxley calculated that, up to the tenth generation inclusive, one Aphis might produce a weight at least greater than that of 500 million men. No wonder Aphids spread quickly, and cause serious loss! Fortunately, they have many enemies. Bonnet, a naturalist of 150 years ago, said: "Just as we sow grain for our benefit, so Nature has sown Aphids for the benefit of many animals." The intelligent ants have a better use for them. They carefully tend them (102:9), getting in return the equivalent of the milk we obtain from dairy herds. Like some other plant "bugs," Aphids exude "honey-dew," probably from the alimentary canal. Perhaps plant sap contains rather much sugary matter for an animal, and the surplus is exuded. A waxy substance, appearing first as oily drops, comes from the so-called "honey-tubes," whose use is uncertain.

Ants benefit the plant by taking the honey-dew, which prevents the leaf from working by blocking the pores, and also supports a black fungus, "sooty mould." Another bug produces the "rain" of "weeping trees."

Were Aphids less common and harmful, more interest would be felt in them, for few animals are more wonderful. The life-history may be extremely complex. One species passed through twenty-one different forms and "parallel series," that is, two distinct life-histories for the same species are known.

Most Aphids lay no eggs except when food is scarce. Then males appear and eggs are laid. In spring, the young emerge, all females—and young are produced alive, each moves a short distance, thrusts its beak into the plant,

and starts its life of drinking. When conditions become unfavorable males appear, and eggs which persist through the winter are laid. The *Phylloxera*, or vine-bug, is one of the most destructive of these animals. It attacks roots as well as twigs. Ravages on twigs can be treated, but the damage to roots is hidden, and is often serious before being noticed. Phylloxera is a native of Eastern United States, where it is not a serious pest to the wild vine. Vines are grafted on resistant stocks imported from America. The Woolly Aphis (123: 2) of the apple-tree, covers itself with a soft white fluffy excretion; it attacks roots as well as twigs, so that apples are usually grafted on a resistant stock such as Northern Spy.

The *SCALE INSECT Coccus* (*Coccidae*) is related to the Aphis. Many have coverings or scales over them, hence the name, scale insect. Many Coccids, multiplying rapidly, are serious pests. One of man's best helpers in dealing with them is the ladybird. It is convenient to group Aphis and ant; scale and ladybird, although ants also get honey-dew from scales, and some ladybirds eat Aphids.

Turning over several of the black flat scales (123: 6) on an ivy or other leaf, you see the soft-bodied insect beneath. It often loses its legs, and does not walk after the scale is formed. It has a long sucking beak, by means of which it takes food. The wingless female stays under the scale. The small male has two wings. The young walk to a fresh part of the leaf, insert the beak, and soon lose their legs. Mussel scales (123: 5) often crowd the bark of apple and other trees. Coccids produce honey-dew, and are tended by ants. On a eucalypt or Acacia, may be clustered spherical whitish bodies, often as large as field-peas (123: 3). These are "acacia scale" insects. The busy ants are taking sticky honey-dew away.

Some scale insects form a scale of a waxy secretion and the cast-off skins. Other Coccids, *e.g.*, cottony cushion scale (123: 4) produce a substance resembling cotton threads instead of a scale. Some make a glassy covering; in the West Indies these are called "ground pearls," and are used as ornaments. Others (*Brachyscelis*) cause the large "acorn gall" (123: 8), and the winged galls (69: 11), so common on eucalypts; the large shapeless, wingless female

scale insect is well protected and well supplied with food; close to the female gall are small narrow male galls; from each a minute two-winged male emerges. Another Coccid produces a substance used as food by the Arabs, and probably identical with the "manna" of Scripture.

A romance of natural history is the story of the introduction of the cottony cushion scale into California, and other countries, and its practical eradication by the Australian ladybird. The remarkable disappearance of the introduced cottony cushion scale about Auckland, New Zealand, was due to the accidental introduction of the ladybird. This large scale insect, which lives here on many plants, without doing much damage, was introduced into California. Being freed from its natural enemies, it threatened the orange growers with ruin. All efforts to check it were vain. The growers sent men to discover the natural enemy of their fast-spreading enemy. In Adelaide, a ladybird was discovered eating the scale on an orange tree. The scientist had found what he was seeking.

Ladybirds (107:8; 127:9) were sent to California; they bred quickly, and attacked the scale insects voraciously. The "niggers," peculiar dark prickly-skinned larvæ, also eat these soft-bodied animals. Soon the pest was checked. It next appeared in the Sandwich Islands; ladybirds were sent over, and the danger was removed. The bug later appeared in the tea-fields of India; again the insatiable natural enemy proved valuable. South Africa was next visited, and, after some trouble, the pest was suppressed. Then Egypt was visited by this soft-bodied bug, called a "mealy bug" in America. The ladybird was again successful. The orange fields of Portugal were invaded by the "mealy bug," and again the ladybird won. Around much of the globe the little ladybird has made itself famous by checking a serious pest. Some experiments with ladybirds have resulted in failure, because the wrong kind was used. Each kind seems to have its own food animal. The ladybird that eats the scales on the eucalypts is not the one that eats the cottony cushion scale. Scale insects in general are also kept in check by the larvæ of several moths, two-winged flies, and Ichneumon-flies.

Some scale insects are of economic importance—some, *e.g.*, the mealy bug, as foes; others as friends. Certain coloring materials, such as cochineal (123:7) and crimson lake, are the ground-up bodies of scale insects. The cochineal insects were bred on cactus plants in Spain and other countries, but the introduction of coal-tar dyes has much lessened the demand for these insects.

ORDER IX.—THRIPS, FRINGE-WINGS.

THYSANOPTERA (*thysanos*, A FRINGE).

This small group consists only of one cosmopolitan family of insects, called thrips (123:9, 9^1; 126: 18). The wings have a fringe of hairs, hence the name, fringe-winged for the order. Many kinds have been spread widely on garden plants. A small common introduced form about 1-16 inch long does much harm to gardens, and also native plants. The peculiar suctorial mouth is complicated. The larvæ resemble the parents, though the pupa is sometimes a resting form. Some live on plant juices, some on pollen. The giant of the family is an Australian thrip about half an inch long. Some Australian forms live in remarkable galls on native plants, and survive long-continued droughts.

BREEDING, COLLECTING AND PRESERVING INSECTS.

Many will desire to study the life-history of at least some insects. It is convenient to keep these close at hand, but the conditions must be as near natural conditions as possible. A few may desire to form a collection of insects, though nature-study is concerned mainly with the living, active animal, and but little with the dead. The best specimens of butterflies and moths are those bred from caterpillars.

A chalk-box makes a convenient breeding-box. Two disused quarter-plate negatives washed off form a perfectly-fitting lid; the bottom is replaced by fine gauze. The caterpillars are kept on a branch of the food-plant standing in a bottle of water, and replaced when necessary. Some larvæ pupating in the ground require an inch of soil in the bottom of the box. A piece of wood containing wood-boring larvæ can be kept in a glass jar covered with gauze.

When collected in the field, beetles are placed in methylated spirit or killed in the killing bottle (124:2), where

plaster of Paris covers the deadly poison beneath. When dead, the insects should be pinned out on a pinning-board (124: 3), made with two strips of linoleum or cork, with space for the body of a moth between. Wings, feelers, and legs should be held in position by strips of paper and fine entomological pins (No. 5), which do not rust. The pin should pass through the center of the chest of a butterfly,

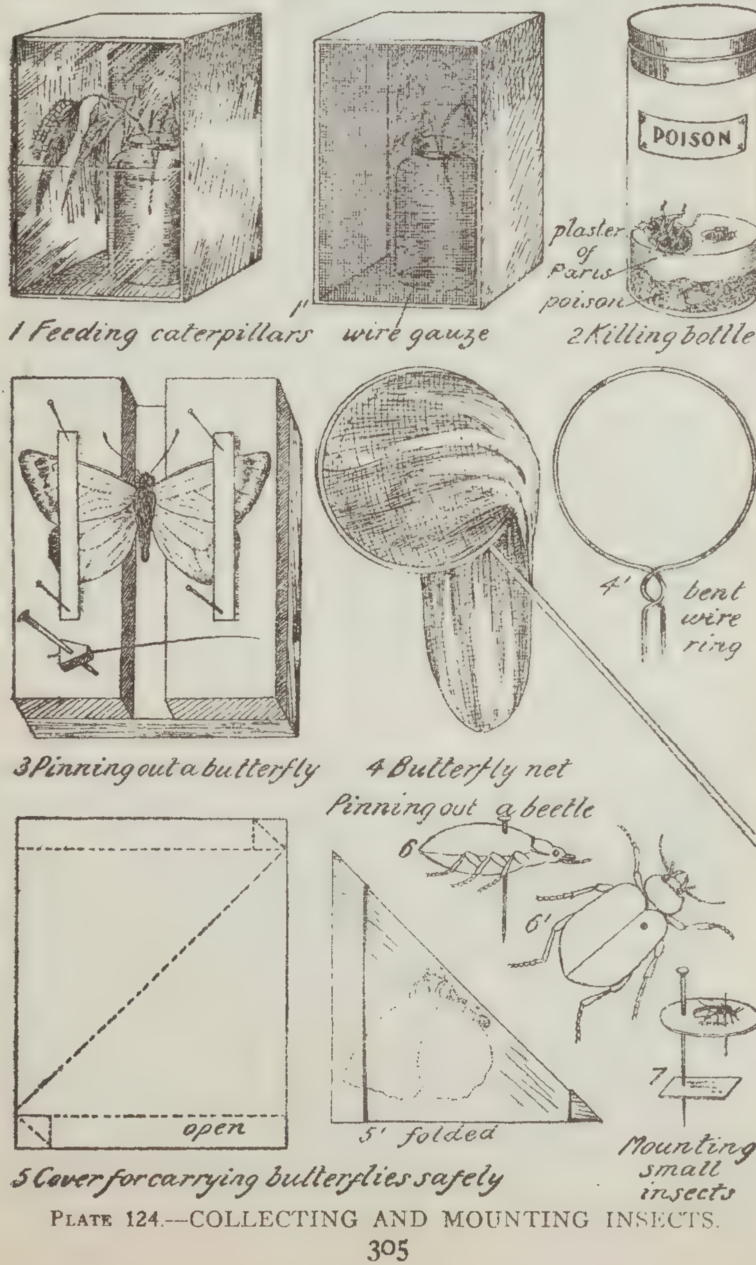


PLATE 124.—COLLECTING AND MOUNTING INSECTS.

but through the right wing cover of a beetle (124: 6^1). A bristle in a small piece of cork (124: 3) on a short pin is used as a tool to work feelers, legs, and wings into position. Small fragile insects, *e.g.*, mosquitoes (124: 7), are pinned above a small card, then a stout pin passes through this card and another, which gives the name, date, collector, and locality. This information should be with every insect.

When quite dry, the pinned-out insect should be transferred to a glass-topped drawer or case, dust-proof and pest-proof. Moth balls, naphthalene, or benzine should be used to keep away or kill museum pests. The case should be covered from the light, except when being observed. Light causes the specimens to fade.

A neat, safe envelope (124: 5, 5^1) for storing, carrying, or transmitting butterflies is made by folding paper, as in the diagram. A butterfly net (124: 4) is easily made by bending a piece of stout wire, as shown in the diagram. The gauze net is then threaded on, and the wire is fastened securely to a suitable handle. By turning the handle, the expert user prevents the escape of a captured insect.

Indiscriminate collecting without details of time and place should be discouraged. A well-arranged and well-kept collection is a great stimulus to study, and develops habits valuable in later life; but haphazard collecting is harmful and cannot be recommended.

THE HOMES OF INSECTS.

Homes of insects interest most nature-students. The paper (125: 1; 101: 1, 2) and mud (101: 5) nests of wasps are familiar objects; many are stocked with spiders, and some with caterpillars. The larva is well cared for. Cocoons of moths (115: 1) provide the silk of commerce, and also provide a fairly safe home for the animal (108: 4; 115: 1) during reconstruction into a winged moth. Ichneumon-flies (100: 4) sometimes, however, break through the defence, and with the aid of the egg-placer lay eggs in the animal within. The cocoon of the Gum Emperor moth (125: 2; 112) is figured as an example. The ant-lion's pit (125: 3; 99: 1^{iv}) is not properly a home. Still the larva is at home to any wandering insect unfor-

tunate enough to get into this most effective insect-trap. Larvæ of leaf-miners or tunnellers (125:4; 118:10) have a safe, easy life, with abundant food *in* the leaf of plants, such as the garden nasturtium or the sow thistle. The adult is a small two-winged fly.

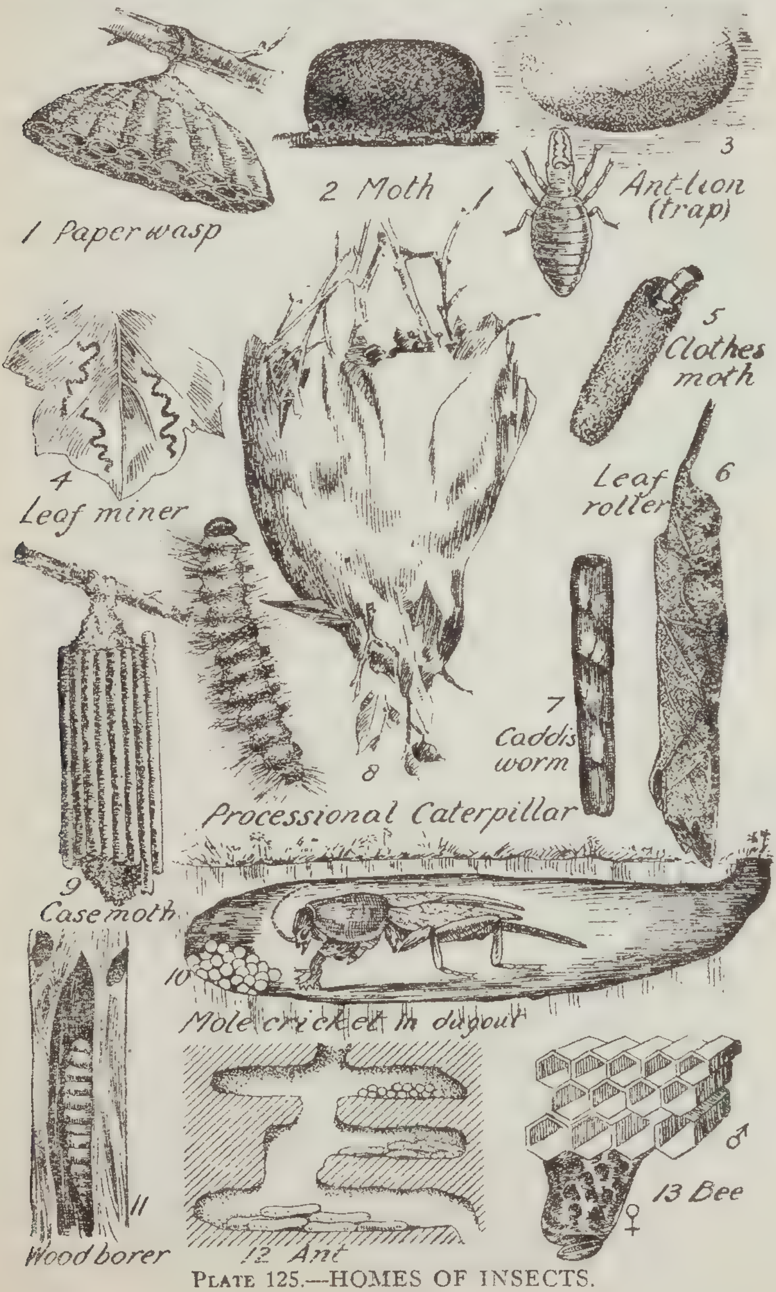


PLATE 125.—HOMES OF INSECTS.

The silk home of the processional caterpillars (125:8; 113:1^{1}) is a common object on "box" trees in the north-east of Victoria. The larvæ shelter here by day and feed by night. The moths are called Bag Shelter Moths.

Clothes-moth larvæ (125:5; 115:3) make a home like that of the casemoth (125:9), or caddis-fly larvæ (125:7).

Caddis cases (125:7; 98:3^{iii}) are used by the aquatic larvæ of caddis-flies, and casemoth larvæ use a similar stick, leaf, and silk home. The casemoth larva (116:1-4) provides one of the best of nature-studies, and the reader is advised to see the description under case moths (116).

Leaf-rollers (125:6) make interesting homes by rolling leaves together. Sometimes they damage lucerne crops or apple-trees. The mole cricket has a dug-out (125:10) often in the vegetable garden. It serves as a safe resting-place for the eggs, as well as for the burrowing adult. Wood-boring larvæ (125: 11; 107:6^{1}) of moths and beetles usually live safely in trees, and cause much destruction of valuable timber. Wood peckers being absent from Australia, many pests flourish here almost unchecked, except for the efforts of rare strong-billed black cockatoos.

The social bees (125:13; 103) and ants (125:12; 102: 5), make remarkable homes. The hive bee not only stores honey in wax cells, but makes three sizes of cells as abodes for larvæ of workers, males, and queen.

An ant's nest has many galleries occupied by eggs, larvæ, and pupæ in silk cocoons. These are tended by the faithful, hardworking nurses; they feed, wash and guard the larvæ and pupæ, and help the young to emerge. Worker ants, as well as queens, live for years, and a nest is a permanent home until circumstances compel a change of abode. Termites' mounds are also permanent homes (93: 8), forming a feature of the landscape in parts.

DESTRUCTIVE INSECTS.

Many insects are destructive pests, and cause serious loss, but some are valuable and hold noxious insects in check. Most universities and agricultural colleges and departments now deal with economic entomology.

The short-feelered grasshopper (126:1; 95:1), the plague locust of Asia, Africa, America and Australia, is

well known. Though considered a valuable foodstuff by some African tribes, it is a serious enemy of man. The young, wingless larvæ walk or hop. The adults fly long distances. The strong, biting mouth-parts enable them to remove all green and succulent vegetation, leaving a "desert" behind them. The greasy bodies of the larvæ have sometimes stopped railway trains in Victoria.

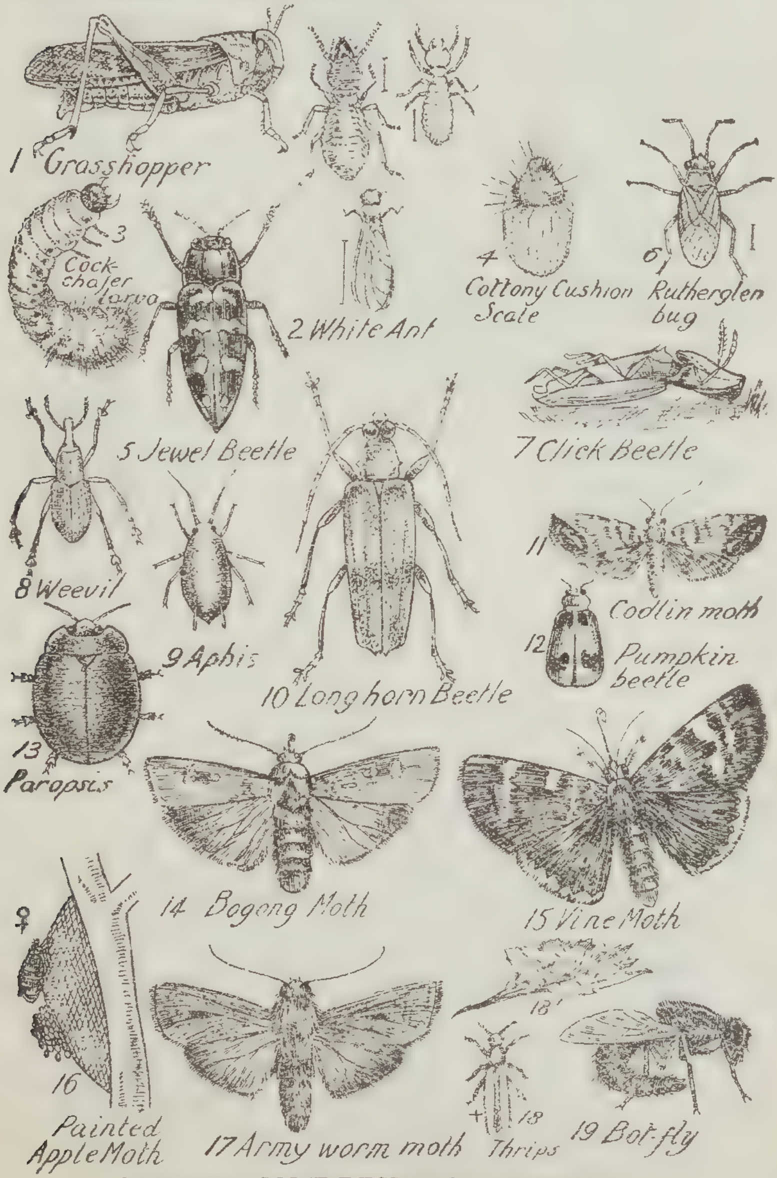


PLATE 126.—SOME DESTRUCTIVE INSECTS.
2, Termite.

The eyeless soft-bodied termites (126: 2; 93) are amongst the most destructive of insects. Their ravages are serious in Australia as well as in most warm countries.

White grubs (126: 3; 106: 5[1]), cockchafer beetle larvæ, are pests in lawns, pastures, and sugar fields. Starlings and the Australian magpie (142: xxi d) dig them up and are valuable friends in this connection.

The cottony cushion scale (126: 4; 123: 4), the "mealy bug" of Americans, is, fortunately, held in check by the little ladybird (107: 8).

The small Rutherglen bug (126: 6) allied to the chinch bug of the United States, is likely to become a serious pest to farmers and horticulturists. Its silver-grey wings render identification easy. It was very abundant in the spring of 1916. It takes its name from Rutherglen, a vineyard and gold mining district near the Murray, in Victoria.

Jewel beetles (126: 5; 106: 6), honey-feeders frequenting the flower of Sweet Bursaria and other native plants, have destructive wood-boring larvæ.

Click beetles (126: 7; 106: 7), on summer evenings, sham death round the lamp on the table. The larva, the "wire worm," destroys pastures, for two years or more.

The apple root-borer (126: 8; 107: 4) is a weevil, one of a most destructive family. This pest of the orchard eats roots, many weevils eat stored food such as wheat.

The Aphis (126: 9; 123: 1) plant-louse, or "green fly," is a well-known garden pest very common on rose bushes. It has been treated elsewhere. Longicorn beetles (126: 10; 107: 6), often with very long feelers, have destructive wood-boring larvæ. The Codlin moth (126: 11; 115: 2) larvæ destroy many apples and pears every year, though spraying with arsenate of lead is giving satisfactory results.

The pumpkin beetle (126: 12; 107: 9), during recent years, has proved a pest, eating leaves of plants of the pumpkin and melon families. It somewhat resembles a ladybird, and sometimes escapes treatment.

Paropsis (126: 13; 107: 7), a dark-brown, almost hemispherical beetle, is a native leaf-eating beetle. It has recently reached New Zealand, doubtless introduced on plants. It does a little harm to native plants. An American relative, the Colorado beetle, is a pest of potato crops

Bogong moths (126: 14; 115: 5), and Army-worm (126: 17; 115: 4) moths are adults of two plague caterpillars, sometimes referred to as "take-all," or "cut-worms."

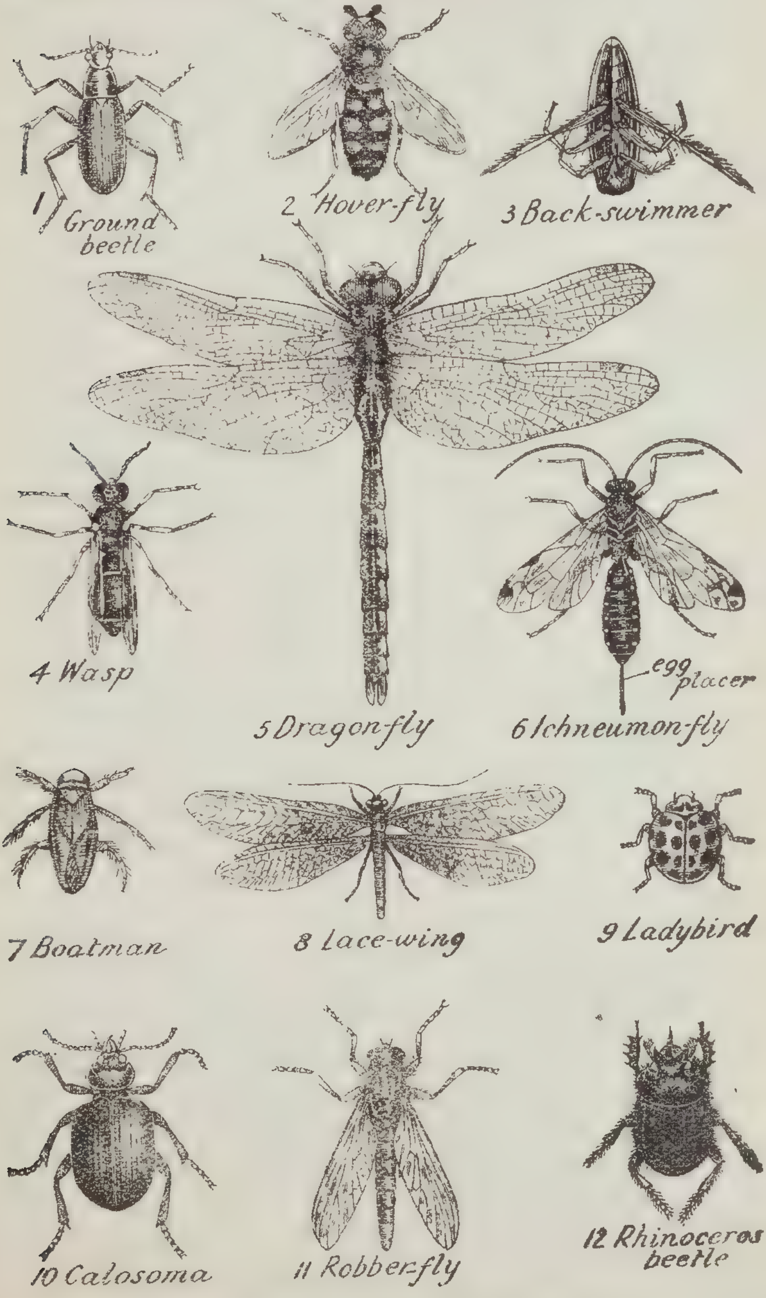


PLATE 127.—SOME BENEFICIAL INSECTS.

The vine-moth (126: 15; 114: 5; 108: 2), and the wingless painted apple-moth (126: 16; 114: 3) are native moths, whose larvæ now feed on introduced plants.

The bot-fly (126: 19; 118: 3), though she cannot bite or sting, is soon recognised by horses. It is an introduced fly, there being no bot-flies endemic to Australia.

Small introduced thrips (126: 18; 123: 9) have been credited with serious damage in orchard and garden.

BENEFICIAL INSECTS.

Fortunately all insects are not pests. Many prey on others, and thus keep them in check; they are therefore beneficial to mankind. The flightless carnivorous ground beetles (carabs) feed on insect larvæ. The carnivorous Calosoma (kalos′-o-ma), beautiful in form and color (127: 10; 105: 5), is not generally recognized as a valuable insect when it enters the house on a summer evening. Hover-flies (127: 2; 118: 2), valuable in garden and orchard, destroy Aphids. The eggs are laid amongst the Aphids, and the adults and larvæ feed on them. The back-swimmer (127: 3) and boatman (127: 7) kill mosquito larvæ in great numbers. Living in ponds, they do no harm. Wasps (127: 4), storing their cells (101: 4) with caterpillars and insects, are friends of the orchardist. The dragon-fly (127: 5; 97: 1) or "mosquito hawk" is entirely carnivorous. Occasionally it might kill a bee. The Ichneumon-fly (127: 6; 100: 4), laying eggs in grasshoppers, caterpillars, and other insect pests, is valuable. The larva of the golden-eye or lacewing (128: 8; 99: 2[11]), the "old clothes' man," lives amongst the Aphids. After eating its victims, it dresses itself in their skins.

Ladybirds (127: 9; 107: 8) have always been favorites with children and others. Since its conquest of the mealy bug (123: 4) on so many different battle-fields in different parts of the world, it is firmly established in favor.

The Robber-fly (127: 11; 118: 5) is a powerful carnivorous tyrant that may fly off even with a large dragon-fly. The rhinoceros beetle (127: 12; 107: 3) is a Scarab, a relative of the sacred beetle (106: 4), of the Egyptians; it buries the droppings of animals, laying its eggs in the same; it is valuable because of its work of soil-improvement.

This beneficial side of insect life is being further developed, and much yet remains to be discovered. Care must be taken in introducing an animal to deal with any particular pest. There is no telling how any animal freed from its natural enemies in one country will act when liberated in a country devoid of such natural enemies. Introduced sparrows, starlings, and gold-finches are common even in remote places, and are still spreading. Introduced rabbits have cost Australia millions of pounds, and are more abundant than ever. Introduced foxes are a scourge, and have already spread far away into the wildest parts of the continent; European earthworms are found far back from cities; the American cockroach is the household insect of some parts of Victoria, and the Oriental cockroach in others. It was thought that Australian animals were not highly enough developed to hold their own, but the Australian cockroach, being freed from its natural enemies, is already a pest in Eastern United States, while the mealy bug (cottony cushion scale) threatened to subjugate the orangeries

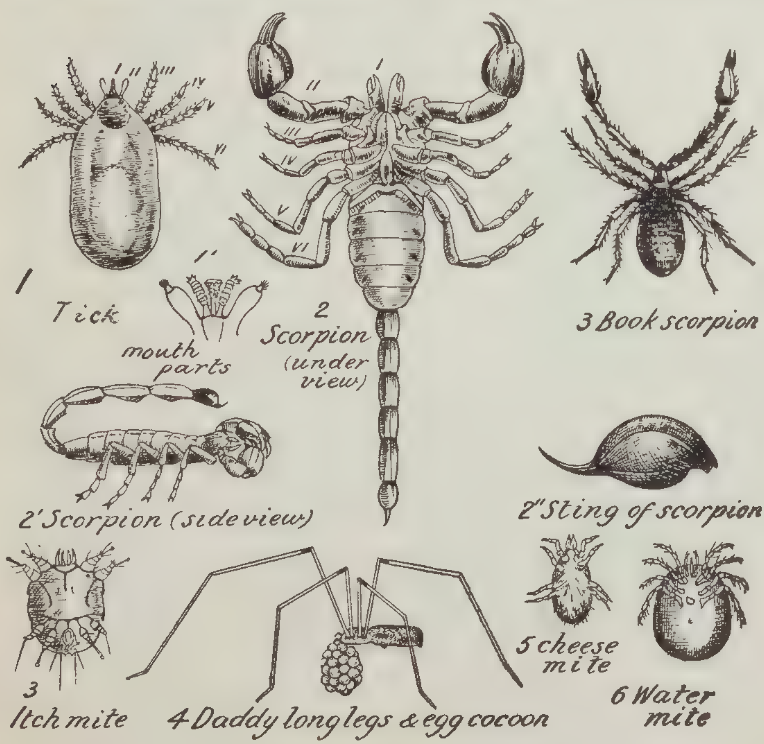


PLATE 128.—SOME ARACHNIDS.

of the world. It is dangerous to introduce any animal, and so free it from its natural enemies.

E.—The Spider and its Allies.

The next class of jointed-legged animals includes spiders, scorpions, ticks, and some other animals.

All have a head-chest bearing six pairs of limbs, and an abdomen, bearing no limbs.

TICKS (128: 1) are carriers of a serious cattle-disease, which has caused much loss in the northern parts of Australia. The mouth-parts (1^1) are piercing and sucking. It is difficult to extricate the barbed mouth-parts of many ticks. Mites have somewhat similar mouth-parts. The itch mite (128: 3) causes an objectionable skin disease. One kind (128: 5) lives in cheese, while the active water mite, *Hydrachna* (128: 6), is known to most pond hunters.

The name of the class is *Arachnida* (*arachne*, a spider).

The scorpion (128: 2) has the first limbs in the form of small claws, while the second limbs suggest the seizing claws of the crayfish. The other four pairs of limbs are walking legs. The nocturnal scorpion breathes by means of four pairs of lung books. The poison sting (128: 2; 2^1, 2^{11}) is in the end of the tail, a long, jointed structure. The scorpion seizes its prey with its claws, and brings the sting over the back (128: 2^1), stabbing the prey with the needle-like point, and injecting a virulent poison. A sting may seriously inconvenience a man. A scorpion stings, but a centipede bites.

The small book scorpion, *Chelifer* (128: 3), has big claws like those of a scorpion, but has no tail or sting. It is often found under bark and possibly amongst old books.

The Daddy-long-legs (128: 4) is harmless. The eight legs are long and slender. The female may be seen in summer with the egg-cocoon. She builds a web in the corner of a little-used shed.

The name Harvestman is given to a somewhat similar though unrelated animal, which has six segments in the abdomen, and does not spin a thread. The second limbs are very long and feeler-like, so that the animal seems to have ten long legs. It is sometimes called Daddy-long-legs also. That name is often applied to a crane fly (117: 4).

THE SPIDER.

Spiders (129), living in most latitudes and temperatures, are successful animals. The size varies from that of the tiny garden spiders to that of the South American giant, preying on humming-birds.

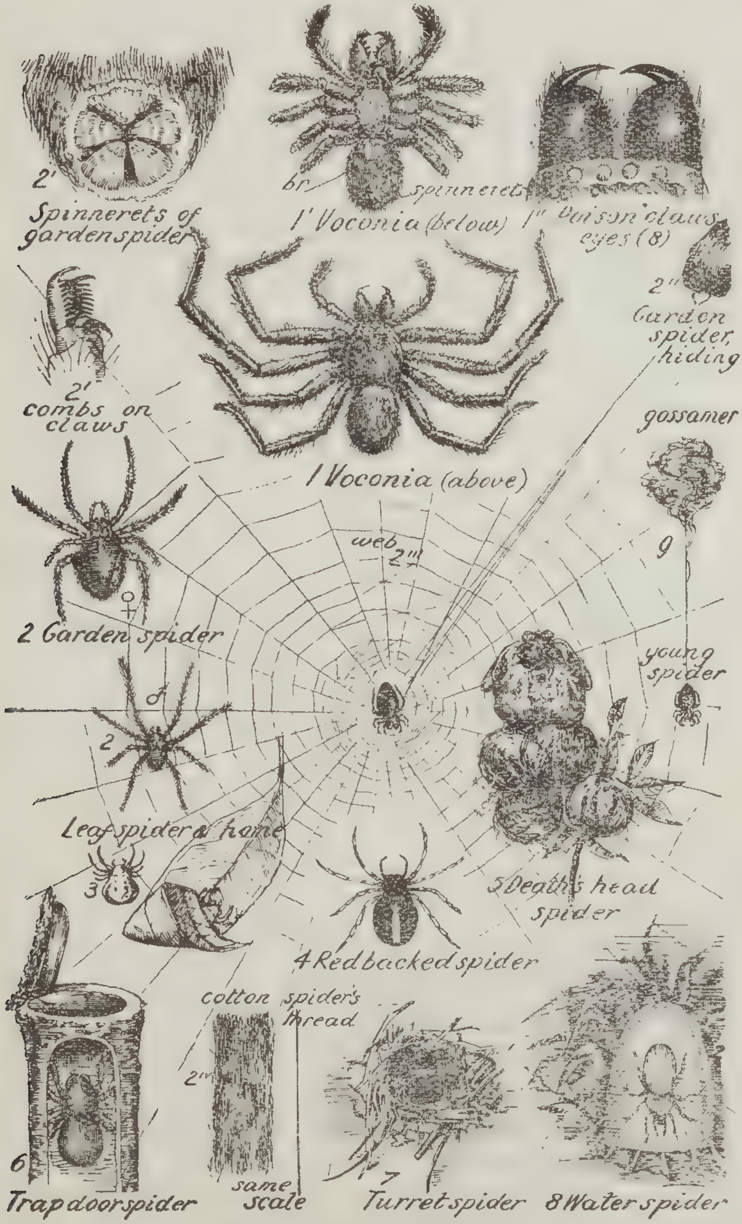


PLATE 129.—SPIDER STUDIES.
5, Death's Head Spider and Egg Cocoons.

Most spiders are protectively colored; animals so colored usually have no other protection. A dangerous, objectionable animal is usually plainly labelled, "advertising coloration." To be recognised as objectionable is best for all. It saves a bright caterpillar a peck, and an inexperienced chick a shock. An inexperienced chicken makes one mistake only. Therefore, beware of the brightly-colored. There is, possibly, one poisonous spider (129:4) in Australia, small glossy-black, with red spots or stripes. It is labelled dangerous. Its bite inconveniences a man, though it is doubtful if it could kill a human being. It is widely spread, New Zealand and Morocco being in its range.

Spiders, with this exception, are less poisonous than mosquitoes, which blister some people. Yet many fear harmless spiders. People formerly dreaded valuable toads, and horse-stingers. The unfortunate *Voconia* (129:1, 1^1) suffers because of this unreasonable fear. Resembling the Tarantula, a Mediterranean spider of bad reputation, that name is wrongly given to it.

The spider is a great insect-destroyer. A full-sized man eating at the same rate would require "a whole fat ox for breakfast; an ox and five sheep for dinner; two bullocks, eight sheep, and four hogs for supper; and, just before retiring, nearly four barrels of fresh fish."

The difficulty of feeding spiders prevents commercial use of the spider's thread. Gloves more durable than those of ordinary silk have been made from it.

Amongst higher animals, males, winning and protecting their mates, are larger than females; amongst lower animals males are often small. Sir John Lubbock has put it graphically. Imagine the male garden spider (2) equivalent to a man 6 feet high, and weighing 160 lbs.; his mate is 80 feet high, and 200,000 lbs. (90 tons) in weight. The small male, however, is brightly colored. The bright coloration of males is generally ascribed to "sexual selection" — the choosing by females of the most attractive males.

The soft-bodied spider has two aids to success: poison claws and poison sufficient for its prey, and the silk thread. According to the use made of the thread, there are all stages of civilization, from hunting ground-spiders to highly-civilized, luxuriously-living, web-builders. The thread is

used by all for an egg-cocoon (129: 5). Having made the eggs secure, the thread makes a snug nest. Then a turret (129: 7) keeps out water or enemies (turret spider). The next step is the unhinged lid, then a hinged door (trap-door spider) (129: 6). A further advance is a snare above the hole. Then comes a silk web in a corner, and, lastly, the geometric web (129: 2^{iii}), a "beautiful example of unconscious art." Meanwhile some use the thread as a suspension bridge; others as a balloon of thread—the "gossamer" (129: 9) used by young spiders dispersing to new places. Another spider (129: 8), with hairy body not wetted by water, makes a "diving-bell" to hold air. Occasionally the young on her back give a water-spider a velvety appearance. There are, therefore, many uses for the silk:—(1) to form an egg-cocoon; (2) to line its hole; (3) to form a turret; (4) to form a trap-door; (5) to make a web, or snare; (6) to make a suspension bridge; (7) to make a balloon; (8) a diving-bell; and (9) a leaf-home (129: 3).

Spiders (129: 1) have two parts, head-chest bearing six pairs of jointed limbs and body. The short poison-claws (1^{ii}) close like a pocket-knife, injecting poison enough for its prey. The small second limbs, the "palps," are used occasionally to clean the poison claws. The flattened bases are jaws; a spiral may be on the inner part of the end-joint of the palps of the male. The eight jointed walking-legs are similar. The longer first leg is a feeler, and the last leg, with combs and hooks (2^{i}), helps in spinning.

The several eyes (1^{ii}) probably see clearly only at short range. The spider depends on touch. With its foot (2^{ii}) on the line, it knows what insect is captured. If a mosquito, too weak to break loose, it does not go out; if a large fly, the spider kills it; if a wasp or bee, a small spider, believing that "discretion is the better part of valor," allows it to break loose, or hampers it with silk.

Under the body are four to six spinnerets (2^{i}), each perforated by possibly a thousand holes. From each hole silk may come. The thread is thinner than it looks. The illustration (2^{iv}) shows No. 40 cotton and a spider's thread equally magnified. On a sunny day, try to catch gossamer threads. As you lose the reflection of light, they are in-

visible, though consisting of from 4,000 to 6,000 threads twisted together. At will, spiders produce different threads, glands with different silk communicating with the spinnerets. A sticky thread, with sticky blobs on it, forms the spiral of the web; a thick strong thread forms the radiating lines. Authorities differ about web-spinning. This means, probably, that different species proceed differently.

Beneath, near the front of the "body," are breathing slits (1^1, br) opening into lung-books, suggesting a book with many pages.

The life-history is simple. The eggs, from 10 to 1000, are laid in the egg-cocoon (5). The young (9) resemble the parents.

CHAPTER XVIII.

SHELLFISH OR MOLLUSCA.

A.—UNIVALVES (*One-shelled Shellfish*).

Shellfish is not a good name for these soft-bodied animals; they are not fish, and some have no shell. Mollusc is derived from Latin *mollis,* soft.

Many one-shelled molluscs, univalves (130-132), are collected on most beaches. *COWRIES* (130: 2, 3) are favorites about rocky beaches, the small *Trivia* (ridged cowry) in particular being collected. The young cowry is not curled over on the outer lip; that grows in later. The big, glossy, spotted Tiger Cowry is often used as an ornament. The money cowry is used as a means of exchange in parts of Africa.

BUBBLE-SHELLS, Bulla (130: 1) are common on many sandy beaches. The animal can swim, but seems to prefer sandy bottoms, where it feeds on smaller shellfish.

The *CLUB SHELLS* (130: 4) are found widely over the world; a very large one, Hercules' club shell, is very common in Mallacoota Inlet.

The *TRITON,* or sea-trumpet, is a large shell, that may be over a foot in length. Related shells (130: 5), with thick ribs, are common on beaches here.

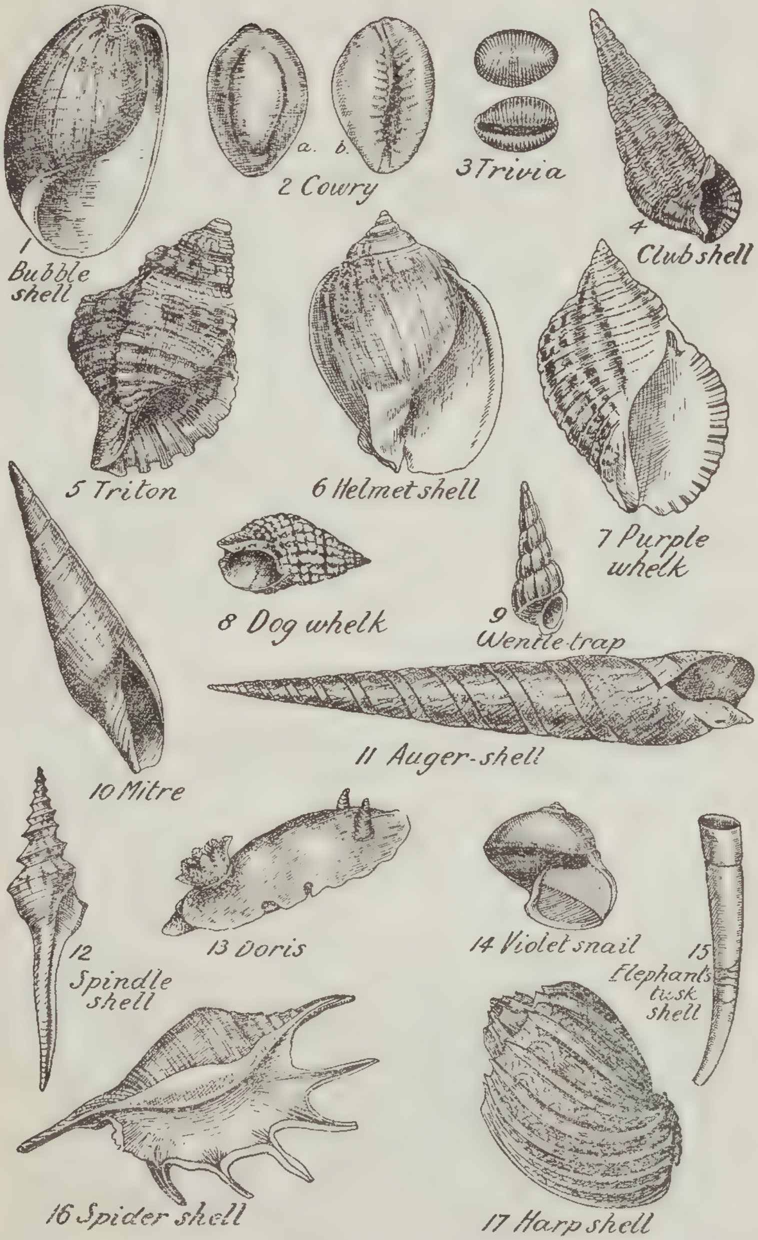


PLATE 130.—SHELLFISH OR MOLLUSCS—UNIVALVES.

The *HELMET SHELL* (130:6) is large, and is prized by amateur collectors. It may be found occasionally on sandy beaches. The animals move slowly over shallow sands, and eat small molluscs. Some are used for cameos.

The purple whelks (130:7) are found on rough, rocky coasts, often subjected to heavy seas. They live mainly in clefts amongst the rocks. Related animals formerly supplied the purple dye of Tyre and Sidon. The Purple Whelk (*Purpura*) is allied to the whelk of Great Britain.

The dog whelk, *Nassa* (130:8), adopted as a badge by the Field Naturalists' Club of Victoria, is a carnivorous animal. It bores a neat countersunk hole in other shells.

The wentle-trap (130:9), with its conspicuous ridges, is an attractive shell. The word is a corruption of the German *Wendeltreppe,* a winding staircase. The bishop's mitre (130:10) is a heavy shell, found on rocky beaches. Auger-shells, or needle shells (130:11), have a long spire; spindle shells (12) have a long canal.

The spider shell (130:16) is one of the wing shells. It is also called the scorpion shell. A related form is the pelican's foot shell, all named from the processes on the lip.

The harp-shell (130:17) is appropriately named, and is fairly common in shell collections.

The floating, fragile "violet snail" (14) may be found on our beaches; it exudes a purple fluid when irritated.

The elephant's tusk (130:15) shells, *Dentalium,* are open at each end. The animals form a separate class.

Doris, the sea-lemon (130:13), is a Nudibranch (naked gill). The gills stand up in a circle on the back, and can be withdrawn. The Sea-lemon is carnivorous, being as destructive in an aquarium as a "hungry fox in a poultry-yard." It is common on muddy flats, under stones; it is often called a sea-slug.

The rock limpets (131:1a, b), common on every rocky shore, are interesting animals. Birds by a sudden blow dislodge them, and eat them, but the slightest touch makes it impossible to shift them. Try it. The head bears a pinhole eye; the tongue about an inch and a half long, is a narrow ribbon, bearing many teeth. A row of "gills" forms the breathing organ. Raw limpets are often eaten for food. Limpets make peculiar tracks in the sand.

PLATE 131.—SHELLFISH OR MOLLUSCS—UNIVALVES.

The keyhole limpet (131 : 2) has a shell too small to hide the body, and the shell has a hole suggesting a keyhole. The current of water from the gills passes out through it.

Chitons, mail-fish (131 : 3a, b), are responsible for the definition of univalves as molluscs with one shell or eight. The shell of a chiton is divided into 8 movable plates. Some Chitons (Ky′-ton) roll up when dislodged. Any rocky beach will yield many chitons. The head bears no eyes or tentacles. Round the edge of the foot is a row of gills.

Sowerby classifies Chitons as multivalves.

The heavy shelled warrener (periwinkle, in Victoria), with a white limy "lid," or operculum (131 : 4), is very common about any rocky beach. It feeds on seaweed. Often the outer horny layer is removed, and the pearly shells are used for ornament. The common Victorian form is called the Australian serpent skin by Figuier, possibly because of the wavy lines of green or greenish violet.

The common black shells, with a whitish apex on the slight spire, are called "crows" by the children on Cape Barren Island. They belong to a widely-spread genus *Nerita* (131 : 6); a good common name is required.

The *SEA-SNAIL, Natica* (131 : 4), though round-mouthed or whole-mouthed, is carnivorous. It burrows in the sand at the end of the long track. The eggs are laid in a sandy collar left resting on the sand when the tide is out.

Top shells, *Trochus,* are common in most collections, and on sandy islands; large ones are used commercially.

The staircase shell (131 : 8) has a remarkable resemblance to a winding staircase in perspective. The turret shell is long and pointed.

The peculiar worm-shell and snake-shell (131 : 10) are regular at first, but, as the animal gets older, the coil is less regular. The shell suggests a worm-tube.

The painted lady, or pheasant-shell (131 : 11), is a beautiful shell, common on weedy flats, about Western Port and other places on the Victorian coast. The pretty shells once brought very high prices in England. The color and pattern vary much, and may change when the animal dies.

Cones (131 : 13), of many kinds, with a long narrow opening, are very common. Some are said to bite the captor; all are carnivorous; one kind is said to be poisonous.

The sea-elephant (131:12) is called also the duck-bill limpet; it has a white, tray-like shell, too small to cover the black animal. It is common under slabs of rock in water at low-tide. It travels slowly.

The volute (131:17) is a member of a very large and widely-spread group. The undulating lines suggest the name *Voluta undulata*.

The European periwinkle belongs to the genus *Littorina* (131:15). Shells of that genus are extremely common here right above high-tide level. Many are bluish, and can be covered by water only at very long intervals.

The Zebra shell (131:14) is a common form between tide levels here. The pearly Mariner (131: 16), when the outer horny layer is removed, is often used for necklaces.

The Wing shell, *Strombus* (131:18), is allied to the spider shell (130:16), already mentioned.

The olive (131:20) is glossy and brilliant, as if recently varnished. Its predaceous occupant is very active.

The *EAR-SHELL, Haliotis* (131:19), is found under rocks in water at low tide. It is sometimes very difficult to detach it. Occasionally, the shell will tear away part of the animal before the sucker-like foot lets go. The "mutton fish" is eaten in some countries, but is now only occasionally cooked here. The shells are very abundant in the aboriginal kitchen middens along the coast. The pearly inside of the shell is used for buttons and ornamental work. As the animal grows, it closes the breathing holes (br.), no longer opposite the gills; a local name is mutton-fish.

The sea-butterfly (132:5), whale's food, is represented much enlarged. Many are very minute, but their enormous numbers render them important in the economy of nature.

The common snail (132:1), land snail (132:8), and pond snail (132:3, 4), have a "lung" with a narrow entrance—the breathing hole.

Most shells have the opening on the right hand when facing the observer, but *Physa* (3b) and *Bulinus* (3c), two pond snails have left-handed shells.

The *SNAIL* (132:1), a good nature-study subject, works just when required. Each child should have two snails in a bottle containing a little water to moisten them. They move, affording opportunity for study. Consider the name

snail. Say snake, sneak. Why should snails have a name similar to "snake"? Perhaps because the animals move similarly. Snails live in damp places, under stones or logs, and amongst grass.

How could you tell if a snail crossed the path? "By the silvery track." Why does it leave the mark? Various answers. Discuss each, and lead the child to see that liquid helps the snail to glide along, the silvery effect being due to dried slime, that once acted as oil.

Observe snails moving up the bottle. The muscles (132: 1[1]) suggest waves like those in grass on a windy day.

PLATE 132.—SNAILS, SLUG, AND SEA-BUTTERFLY.

3, Pond Snails; a[1], *Limnaea;* b, *Physa;* c, *Bulinus;* 6, greatly enlarged.

Draw the animal (1), side view, on the board. Label the body, the head, the foot (flat on the glass), and the shell. The spirally coiled hump always fills the shell. The eyes are on long stalks. Why are our eyes not on stalks? Our extremely sensitive eyes would be injured. How do snails prevent injury? Touch the eye. Eagerly children tell the eye (1^{ii}) is drawn in. Compare the turning of a stocking inside out. A long strap-like muscle (1^{ii}) runs down the hollow eye-stalk. When the eye is touched a message is sent to the brain. The brain sends an order to the muscle, which thickens greatly, turning the stalk down inside the body. Touch the eye again, and, as the body-wall is partly transparent, see it pulled back. Let each feel his thickening arm muscle as the hand is raised.

What else is on the head? "Feelers." As the snail feels with them, they are sensitive. How does it prevent injury? "Withdraws them." Where is the mouth? Two fleshy lips (1^{i}) are at the front border of the foot. The black, horny upper lip (1^{iii}) may be seen occasionally. Having strong ridges, it is an efficient upper jaw. The rough tongue (1^{iv}) scrapes food against the horny lip; it bears a hard, rough plate with teeth suggesting a rasp. The number of teeth is great. To give some idea, refer to children's teeth. How many teeth should a young brother have? Various answers. Count one side of one jaw; two in front for biting; one dog tooth, two behind for grinding; five teeth on each side—20 teeth in the first, or "milk" set. A man has 32 teeth (151 : 1); a child, 20; a snail, about 20,000. As the tongue ribbon wears in front, it grows from behind. We can now understand how the snail does so much damage among tender plants. How do snails breathe? Many guesses. Animals having bones use the mouth or nose when breathing, animals without bones do not use the mouth when breathing. At last, one will see, under the shell, a hole (1^{i}), large enough to admit the point of a two-inch nail; it opens and closes. In a snail crawling up glass, this hole is on the right side. All see it. On the outside of the last coil, for about three-quarters of the way round, in a young transparent snail, see blood vessels (1^{ii}) branching on the roof of the lung. Air is admitted through the breathing hole.

Oxygen passes through the moist skin of the blood vessels, and carbon dioxide passes out.

At the back of the shell, slightly to the left of a young transparent snail crawling away from you, see a white patch—the kidney. Near this, see the beating heart (1^{ii}).

The breathing-hole is in a fleshy "collar," that holds the shell in place. Note, on the shell, "lines of growth" (1) parallel to the edge. As the animal grows bigger, it adds to its shell, forming a spiral home, twisted round a central axis, as shown by the section.

The shell has three layers; the outer is horny; black in a mussel, variegated in the snail-shell. Beneath this is a white layer—the limy layer, strongly developed in some, but poorly developed in the fragile snail-shell. The inner pearly layer, well developed in the pearl-oyster, mussel, and mutton-fish, and thin in the snail, has no lines of growth; it forms a smooth surface to fit the body of the mussel, or the hump of the snail.

In univalves, the horny and limy layers are made by the collar; the pearly layer, by the outer skin of the "hump." The horny and limy layers have lines of growth where successive additions have been made. The outer skin of the hump of univalves or of the body to bivalves, is called the "mantle." The forming of the pearly layer suggests perspiration. The pearly material is excreted from the whole surface of the mantle.

A snail may stay fixed to a leaf for weeks. It forms a lid (131:4) (compare with the white "lid" of the periwinkle) of slimy material; this prevents loss of water. Put so-called dead snails in water; many soon crawl away.

The large snails, common about Melbourne, are introduced snails. Unfortunately, the European snail promises to be a serious pest, and is spreading steadily through Australia. No student should introduce them to his district for the purpose of nature-study.

The slug (132:2) is related to the snail. The much-reduced shell is embedded in the "hood" on the back. It is probably of no use to the animal, and may be disappearing. It is of use to scientists, indicating, probably, descent from animals in which the shell was of use. The breathing hole (br.) is on the right side of the animal.

POND SNAILS often skate across under the surface (132: 4; 187: 9) of the water. They are useful animals in a freshwater aquarium, which should never be without them. They keep down the green coating that grows on the glass. The circular flat egg-mass (89: 20) may be laid on the glass front of the aquarium. Pond snails serve as a host of the liver fluke (74: 3), and for a flatworm (*Bilharzia*) introduced from Egypt by our soldiers.

Planorbis (132: 6) is small, and coiled flat in one plane. The freshwater limpet (*Ancylus*) is also small.

Melania (132: 7), with a high-spired, blackish-colored shell, is found in fresh water, and in some gardens.

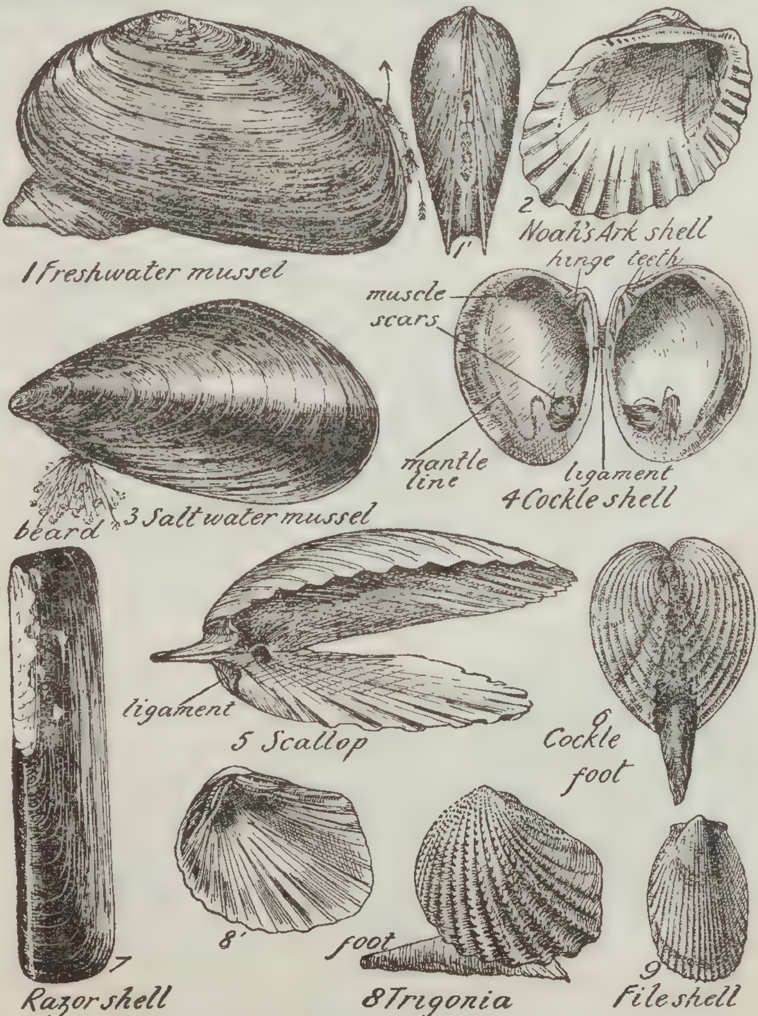


PLATE 133.—BIVALVES

LAND SHELLS (132:8) vary in size, and are found even in dry districts, where they remain coiled up until damp weather comes. They are world-wide from Tierra del Fuego to the northern limit of trees. Many native snails are very pretty.

B.—BIVALVES (*Two-shelled Shellfish*).

The large freshwater mussel (133:1) forms a good study. It will live in a dish of water for some time. If there is sand in the bottom of the dish, it will plough its way along with its hatchet-shaped "foot."

It breathes and feeds by compelling a current of water to flow in through an opening that may be seen at the posterior end. The water passes through the gills, past the mouth, and out at the upper opening. This opening is always complete. The lower opening is complete in the cockle (133:6), but is a slit (1^1) in the freshwater mussel.

The two shells fit together very exactly, teeth (133:4) on one valve fitting gaps on the other; along the upper edge, an elastic ligament opens the shells.

The three layers of the shell are plainly seen (1), the black, horny layer and the limy layer have lines of growth, being added to by the edge of the mantle. The smooth; pearly layer inside is secreted by the whole outer surface of the animal, and shows no lines of growth, though it shows one mantle line (4) where the edge of the mantle is fixed to the shell. In many shells at the rear end is an indentation in this line (4). The shell is closed by muscles fixed firmly to the two valves at two rough patches (4), one near the front and the other behind. Other small muscles have small scars near these.

The Noah's Ark shell (133:2) is a heavy ridged shell. It was extremely abundant about the delta of the Yarra River. On Coode Island is a bed of these shells, nearly two feet thick. The animals are very rare indeed here now.

The salt-water mussel (133:3) is fixed by a beard of silken threads. The front muscle joining the shells is small.

The razor shell (133:7) is common on many beaches. It is long and narrow like a razor blade, and it burrows in the sand. The cockle, *Cardium* (133:6) has a long foot, which can be protruded. By means of this foot, the animal can make small hops. The scallop (133:5) swims freely

flapping the shells together. The narrow ligament holds it open, the muscles close it. The bottom valve is flat and fanlike, and the upper is rounded.

The narrow file shell (133: 9) is rough like a file.

Trigonia (133: 8) is one of the "living fossils" of Australia. It was known fossil in England. The first animal taken alive managed, with the aid of the foot, to fall over-

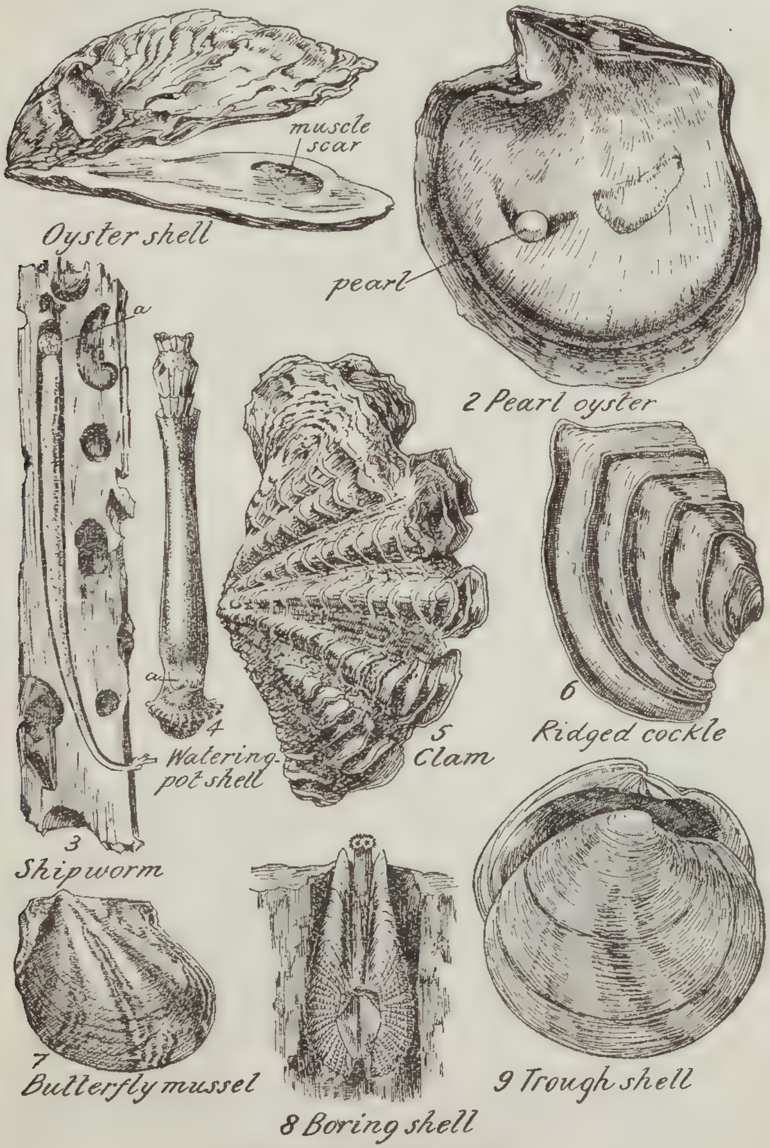


PLATE 134.—BIVALVES.
3, 4, a, The Two Valves of the Shell.

board in Sydney Harbor. The naturalist who missed his specimen was the butt of many remarks for several years, until the next specimen was taken. *Trigonia* is very common in Western Port Bay. Ladies often use the pearly shell (8^1) on hat-pins.

The edible oysters (134: 1), lying on one valve, have one big muscle to hold the valves together. Very large oyster-shells are found on the aboriginal kitchen middens, so common all round Port Phillip Bay, but that oyster is now extinct here, though it lives on parts of the Australian coast.

Pearl oysters (134:2) abound in the warm seas of tropical Australia. The beautiful pearl is a tomb for a parasitic flat-worm, allied to the liver fluke.

A large, pure-white "trough shell" (134:9) is found on some beaches, while the ridged cockle (134:6) is usually rare, and is valued by some collectors of curios.

The butterfly mussel (134:7) is frail. It is a swimming shell that occasionally, after storms, covers a beach.

Boring shells (*Pholas*) bore into rocks (134:8), and hide safely, while the finger-like siphon with the inhalent and exhalent holes reaches the surface.

The giant clam (134:5) of North Australia and of tropical seas is the largest of shell-fish. The two shells may weigh 3 cwt.

The remarkable "watering pot" shell (134:4) gets its name from the perforated plate at the end of a limy cylinder, on the outside of which two small valves (*a*) representing the real shell may be seen. The animal burrows in sand, and remains buried in its cylinder.

A still more remarkable shell-fish is the most destructive ship-worm, *Teredo* (134:3). It riddles planks and piles, boring long burrows with a shelly lining in the hardest wood. This "golly-worm" is a favorite bait on parts of the Australian coast; the two valves (*a*) are at one end of the long, worm-like body.

C.—THE OCTOPUS AND ITS ALLIES.

A small group (135) of highly developed forms is of great interest to nature students; they make up the head-footed order (*Cephalopoda*), the mouth being in the middle of the foot, which is divided into eight, ten, or more "arms" (tentacles).

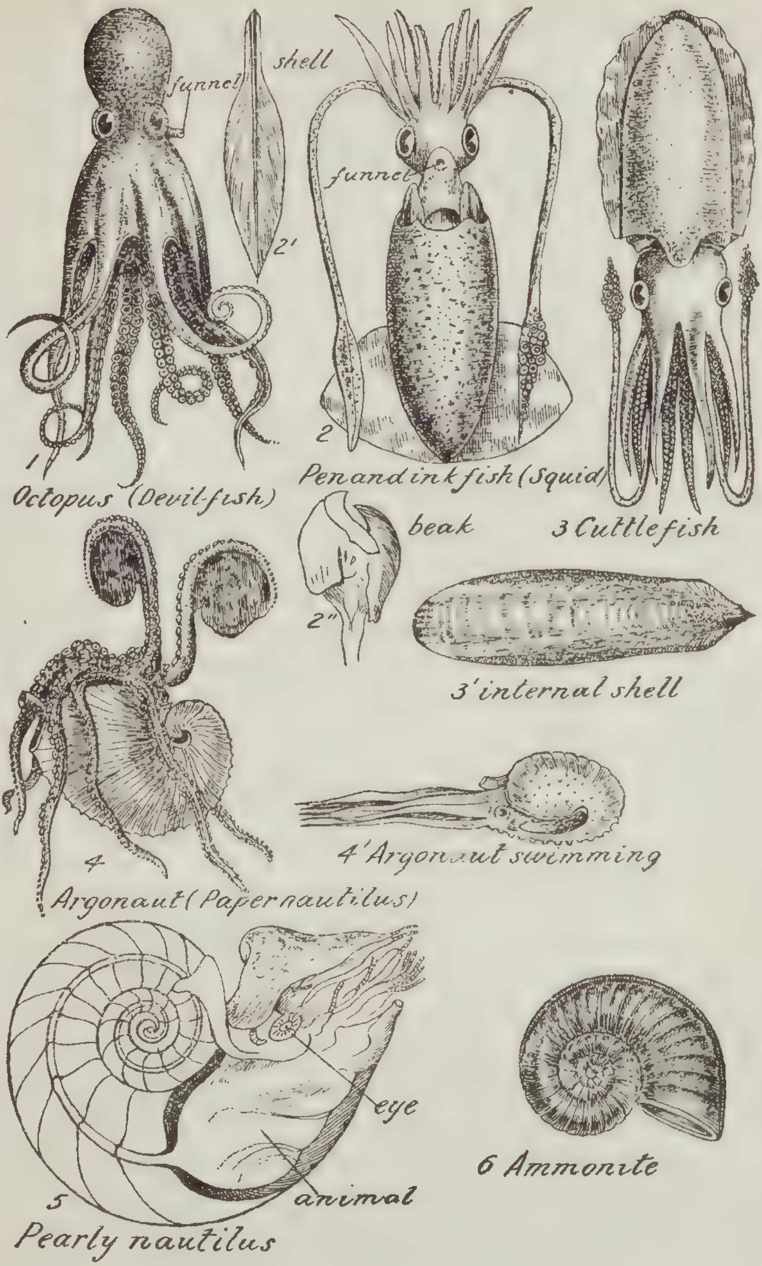


PLATE 135.—THE OCTOPUS AND ITS ALLIES.

5, The shell is shown in section to show the many empty chambers A canal runs back to the centre.

The brain is highly developed, and is enclosed in a cartilaginous skull. The eyes are as perfect as fish eyes. The horny beak reminds one of a cockatoo's beak (2^{1i}), though it is the upper jaw that closes into the lower.

The *OCTOPUS*, or devil-fish (135:1), is well known by reputation. It has no skeleton or shell. The eight arms, furnished with suckers, serve for walking. The mantle cavity containing the two gills can be fastened down by the "hooks and eyes;" the forcible ejection of water from the funnel (2) drives the animal backwards (4^1).

The suckers work by air pressure; they are applied closely, then a piston inside being withdrawn, a partial vacuum is formed, and the feelers grip tightly. When the creature wishes to release its hold, the piston is depressed, the vacuum is lost, and the sucker lets go. Nearly all the group have a dense black ink, "sepia," which can be ejected with the water from the funnel. It hides the animal in an artificial fog from its enemies.

The *CUTTLE-FISH* (135:3) has the shell (3^1) reduced to a light internal structure, fitting in the dorsal hump. The animal has ten arms, two long ones being armed with suckers only at the tip. It can walk on its head, swim forward, with the aid of the fringe fins, or dart backward. The shell is used for fine polishing; there is a considerable demand for it. The clusters of dark purple eggs are sometimes called sea-grapes.

The *SQUID* or pen and ink fish (135:2) has a wider and shorter fin. It can change color almost as well as a chameleon, a lizard famous in this connexion. The shell is reduced to a horny flat pen (2^1). It is said that a famous geologist wrote his report with the pen and the ink from one of these animals that died ages ago. The ink is said to be indestructible. Squid may be a corruption of squirt.

The *PAPER NAUTILUS*, Argonaut (135:4), is one of the most famous of animals. The female has two flattened webbed arms, which manufacture a beautiful perfect home wherein she lives. She is not fastened to the shell anywhere, but lives in it and lays eggs in it, so that it is sometimes described as the egg-case. Tradition, notwithstanding, she does not hoist these flattened legs as sails, but swims as a cuttle-fish does, by ejecting water from

the funnel. She can walk on her arms, the shell being uppermost, but swims shell downward. The tiny shell-less male was for a long time unknown.

Beautiful, small chambered-shells are found rarely on Victorian beaches, but very commonly on Western Australian beaches. These are the internal shells of *SPIRULA,* a member of this group. The small canal that runs into the center of the shell is along the inner side of the coil, not in the center, as in the Pearly Nautilus (5). Though the shells are common, the adult animals are very rarely taken.

Octopus, cuttle fish, squid, paper nautilus (argonaut), and Spirula have two gills in the mantle cavity.

A four-gilled branch of the order is almost extinct. The chambered nautilus alone survives. This animal, as it grows, adds to the shell to fit the widening body. Then, to keep it up in the shell, it builds a platform below it, shutting off many chambers (5). These may contain water, though they have been said to contain air to reduce the specific gravity of the animal. It wanders slowly on its arms, which are numerous, more than ten. It has no ink sac and no complete funnel. The eye has no lens, and is a pinhole eye (83:8). A limpet, *Patella* (131:1) has a similar eye. Ammonites (135:6) were once a big group of animals. They were abundant in Mesozoic times, but are now extinct.

CHAPTER XIX.

SPINY-SKINNED ANIMALS.

STARFISH are of many forms, but always show radial symmetry, so that many diameters divide the animal into two similar parts. Higher animals are bilaterally "symmetrical." Only one line divides the animal in two similar parts. There is no head—any part can be the front. The one plate connected with the water system destroys the radial symmetry to some extent.

Five, or a multiple of five, is a usual number for the arms; the cushion star, so common here, may have from 4 to 40. The large starfish (1) also has a variable number.

Starfish have many tube-feet ($136:1^1$, 2) working by air pressure. By means of these, they walk and turn over. The tube-foot is placed on a surface. The water

within is drawn back into the rounded bladder above (1^1), a partial vacuum is formed, and the foot holds on. In time, water is forced from the bladder down to the inside of the foot, and it lets go; each arm has many tube-feet.

The mouth, a large protrusible sac, is in the center underneath. Starfish are troublesome on oyster-beds, and are said to open and eat half the oysters.

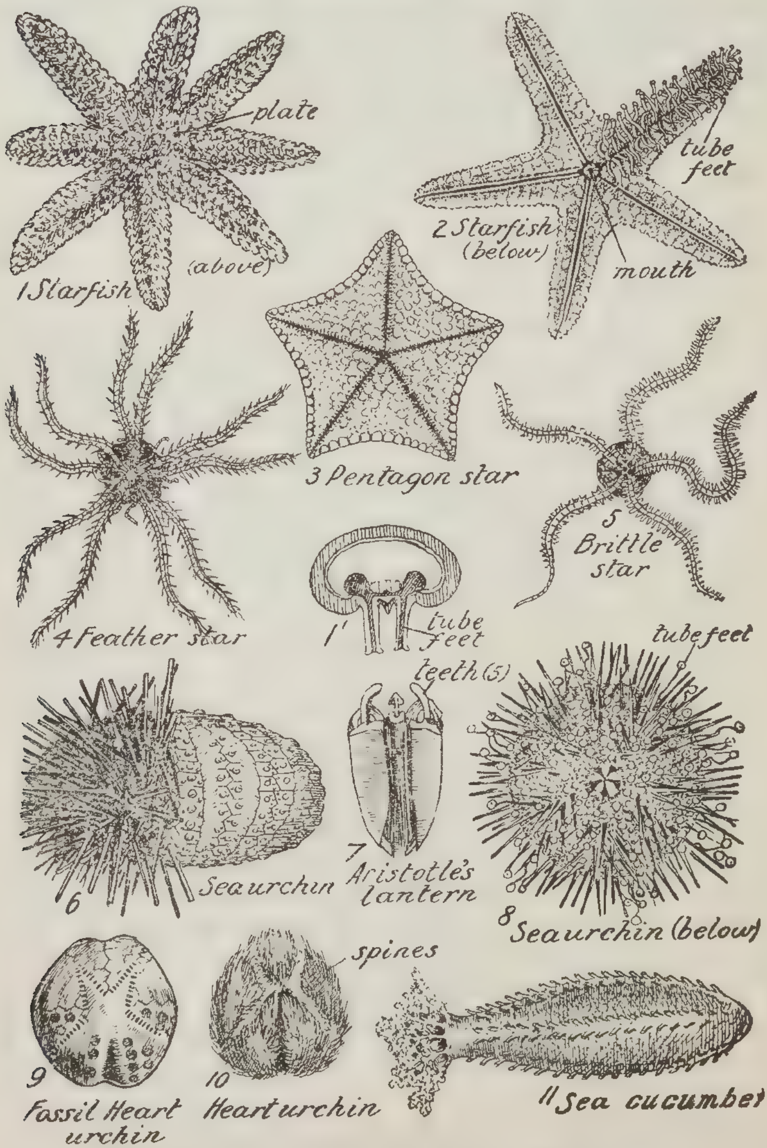


PLATE 136.—SPINY-SKINNED ANIMALS.
1^1, Section of Arm showing Tube-feet; 7, Part removed.

The neat, flat pentagon star (136: 3) is a favourite with young collectors, and dries easily.

BRITTLE-STARS (136: 5), common under rocks, have long spiny arms. It is difficult to collect one whole, as an arm or a part of an arm is easily cast off.

FEATHER-STARS (136: 4) are free-swimmers; they have five double-arms. Round the small disc are anchoring hairs. Sea-lilies, crinoids, were so common in ancient times that their remains constitute masses of marble (crinoidal marble) (165: 5), often used for marble mantlepieces. These interesting animals, like great treeferns perhaps 70 feet high, had jointed stems. A few still survive.

SEA-URCHINS (136: 6, 8) generally called sea-eggs, are interesting. The long spines form an efficient protection; each works on a knob, and is held on by muscles, which, when dead, soon decay away in water till the spines fall off. In those washed up alive, the muscle may dry, holding the spines in place. There are many forms of sea-urchins. They are found in rocky places in water.

A live urchin in a jar of sea-water is interesting. The long tube-feet (8), longer than the spines, are numerous, there being as many as the fine holes seen in five double rows on the dead urchin. They work, as in the starfish.

The remarkable Aristotle's lantern (7) has a tooth working in each of the five sockets about the mouth.

Many kinds of urchins, flattened and developing a bilateral symmetry, are known. The heart urchin (10), sometimes called "sea-mouse," a name applied also to a marine worm (75: 2), of great beauty, is common on some muddy sea-bottoms. One, *Lovenia forbesi* (136: 9) is extremely abundant as a fossil at Beaumaris (Port Phillip Bay), and on the Murray River, South Australia.

The *SEA-CUCUMBER* (136: 11), or sea-slug, is allied to the trepang (bêche-de-mer) of the Barrier Reef. It may throw out its "stomach" when disturbed: it grows another. The power of regeneration of lost parts is considerable among the lower animals.

On account of the development of the larva, suggesting a connexion with backboned animals, the radial spiny-skinned animals are sometimes placed at the head of the invertebrates, leading on to the backboned animals.

CHAPTER XX.

LOWER VERTEBRATE ANIMALS.

The name Chordata is replacing Vertebrata, because, in the lower forms, the backbone has no vertebræ.

There are eight classes of chordate animals constituting the phylum Chordata. These are:—(1) Tunicates, sea-squirts; (2) Cephalochorda (lancelet); (3) Lampreys; (4) Fish; (5) Amphibians, frogs and toads; (6) Reptiles; (7) Birds; and (8) Mammals.

Tunicates (137: 5, 6) form the class Urochorda (*oura,* tail), so called because of the rod of gristle (backbone) in the tail of the free-swimming tadpole-like larva. The larva settles down, loses the tail, and develops its coat (tunic) of cellulose. A current of food-bearing and oxygen-bearing water passes in at one aperture (5) through the gills on the throat, and out at the other. Squeezing causes a thin jet of water to issue from the two holes; hence the names sea-cows and sea-squirts.

Some tunicates swim, most are fixed, and some form colonies (6). Some have a thin transparent coat, some incorporate sand-grains in the coat, while some, bigger than a man's fist, have a thick cellulose wall. The colonies (6) are often of small individuals, and may be seen at low tide in water on the under side of a rock. Tunicates, and some worm-like forms, are primitive chordates.

The lancelet (137: 7), a primitive, skull-less, fish-like form about two inches long, is common in places. The notochord (backbone) is continued into the head, hence the class name Cephalochorda. The lancelet is usually buried in mud or sand. It obtains food and air from a current of water passing into the mouth, through the gills, and out at the water-pore.

Lampreys (137: 8) suggest eels, but have seven small gill-holes, and no jaws or paired limbs. The backbone is a rod of gristle. Because of the round, sucker-like mouth, the class name is Cyclostomata. Two families are represented in Australia. The small Mordacia (*mordax,* voracious), about one foot long, has been caught, fixed to

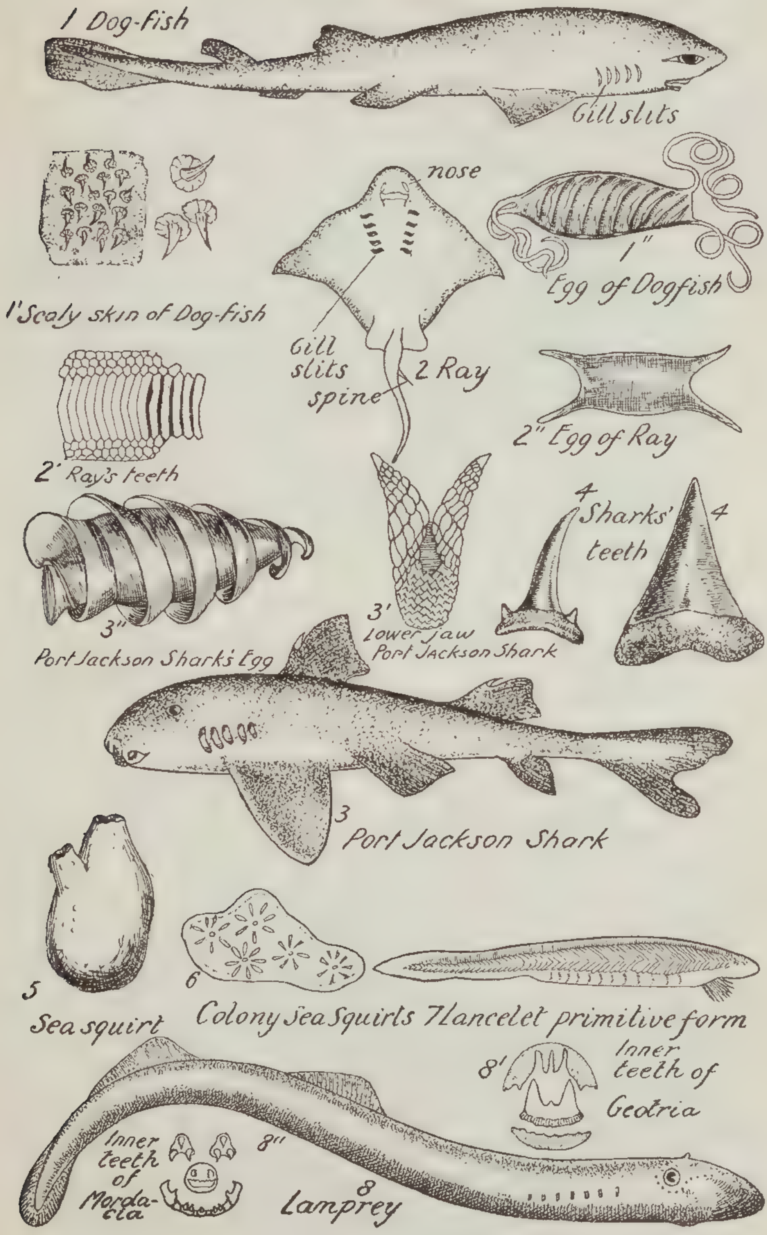


PLATE 137.—BACK-BONED ANIMALS. TUNICATES TO FISH.

a barracouta. It rasps the flesh off with the tongue-teeth while clinging with the sucker-like mouth armed with horny teeth (8^{ii}). The one nostril opens near the eyes.

Geotria—the type of the other family—is about 22 inches long, and may have on the throat a large pouch of unknown use. The horny central teeth (8^{i}) are quite different from those of Mordacia.

Lampreys enter rivers to lay eggs. The writer has seen many ascending the Hopkins River Falls during an eel-fare in November. Identical forms are found in New Zealand and Chili, one evidence of a comparatively recent connexion of Australia, South America, and New Zealand.

CHAPTER XXI.

SOME FISH STUDIES.

Few animals are so well adapted to their environment as fish (137: 138). Most fish have the same general outline and structure; life in the dense water medium has impressed itself on them, developing the tapering, rounded-wedge fish-shape.

Seeking food and mates, and escaping danger, fish (138: 1) move rapidly. There is no neck; and no projecting shoulders offer resistance. From the front, the body is oval; from the side, a double-rounded wedge, tapering to front and rear in clean, well-cut lines. Man expends much energy in supporting himself; the fish spends little. The large lidless eyes, flush with the surface, move little. There are no external ears. Smell is important to fish, and the nostrils are easily seen. The mouth, large or small, is a slit at the front end—a shark's mouth (137: 1) is under the head. No fish has a protrusible tongue. The teeth vary from the sharp, seizing teeth of barracouta, to the crushing pavement (137: 2^{1}) of rays which eat shellfish.

Fish have a protective covering of scales (138: 1), embedded in skin in front and free behind. Further, to lessen friction, the fish is slimy. The "*lateral line*" (138: 1, 5) along the sides is a series of sense organs.

Fish have effective organs of locomotion (fins and tails). The side fins, suggesting oars, never exceed two pairs. The thickest part of the body being above the center, dead fish float belly upwards. The paired fins, though they assist in locomotion, are mainly balancers.

The "chest-fin" is behind the gill-cover. The "hip-fin" varies in position, far back, under or even before the chest-

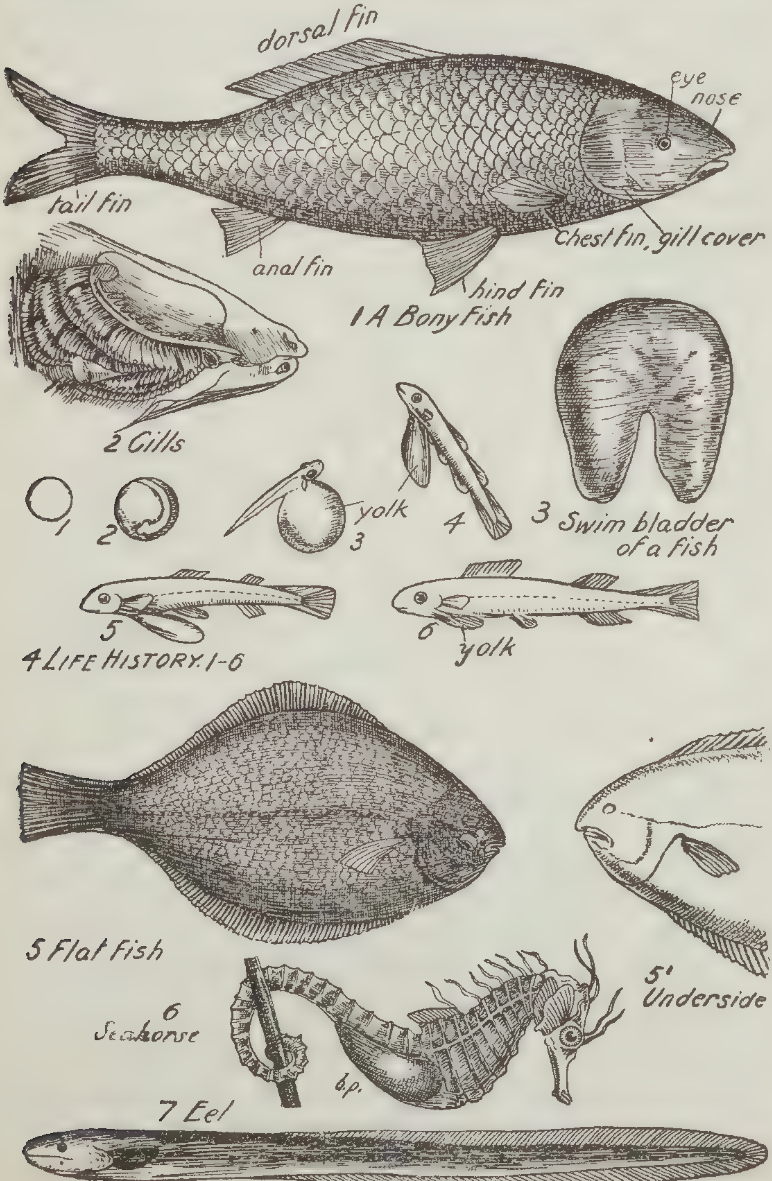


PLATE 138.—BONY FISH.

fin. Hip-fins may be absent, as in eels (138: 7); chest-fins (137: 2) are enormously enlarged in rays, and are elongated parachutes in flying-fish (147: 14).

The median fins, varying in number, suggest the "center-board"—the sliding keel of yachts; they increase stability.

The chief organ of propulsion, the tail, works from side to side like a single sculling oar. It is probably superior to a screw propeller. The curves of the body increase the speed. The tail, suggesting a rudder, also steers. It is worked by muscles, which form the part of the fish used for food; we eat muscle whether eating fish, fowl, or beef.

Rays have a lash-like tail (137: 2), with a barbed spine, a nasty weapon. The tail of the sea-horse (138: 6) holds on to weeds.

Living things breathe oxygen, and breathe out carbon-dioxide. Fish avoid the surface if the water is in good condition; they take water in at the mouth, pass it through the gill-slits (2), and out under the gill-covers (1). Water dissolves substances, such as sugar, salt, and air. To show that air is disolved in water, take a glass of *cold* water into a warm room. See, later, bubbles of air on the glass. The warming water (189: 1) dissolves less air. Fish get oxygen from the water, which removes carbon-dioxide from the blood in the gills.

When a fish is out of water, the gills are dry, and osmosis cannot take place: the fish drowns. If we are in water, oxygen cannot enter the lungs, carbon-dioxide is not removed, and we drown. Fish are cold-blooded, their temperature is that of the water.

Possibly, no animals outrival live fish in brilliant coloration; yet this color is almost solely protective. Brilliant coral-fish and parrot-fish are invisible in coral lagoons until they move.

Protective coloration and form possibly reach their climax in the Leafy Sea-horse of Port Phillip Bay; leaf-like processes harmonize with the weedy surroundings. Possibly gaudy leather-jackets, with a dangerous spine, show "advertising coloration." "Alluring coloration" is shown by the small Coral Sea *Amphiprion*, which, when chased by a larger fish, dashes to a gigantic sea-anemone, that captures the pursuer; decoy and anemone share the prey.

Within narrow limits the fish can adjust itself exactly to the density and pressure of the water. The swim bladder (138: 3) assists in this adjustment. Deep-sea fish rising to higher levels cannot regain their proper station; they rise to the surface and often burst.

Fish, like birds, have definite migrations. Sharks from Port Phillip Bay move north before winter. Mr. D. G. Stead, in his "*Fishes of Australia,*" shows that many fish migrate north. The floating eggs are carried south by the current, to the coast where the parents lived.

The eels of Northern Europe travel west to the edge of the continental shelf, produce eggs and die. The young enter rivers, when from 3 to 6 inches long. Many young eels, "elvers," scale the perpendicular Hopkins River Falls in an "eel-fare" in November. They work upstream, and even across a wet field to unexpected places. Attaining maturity, they return to the sea, produce eggs, and die. Eels, extremely rare north of the Victorian Divide, apparently do not enter the Murray.

Some fish lay over 1,000.000 floating eggs; some attach the eggs to weeds, other eggs cohere, others are laid in a nest and carefully guarded. The male sea-horse carries the eggs in a pouch. Most sharks are born alive, but some, including skates, rays, and dog-fish, and that "living fossil," the bull-shark, Port Jackson shark, or pig-fish (137: 3), lay horny-shelled eggs—the "mermaids' purses" —common on beaches. The Port Jackson shark crushes shell-fish with its peculiar flat teeth (3^1). The teeth were known as fossils before the animal was found alive here.

Many interesting life-histories of fishes have been recorded; many need study. Fish begin life as a single cell, an egg containing food (4^1) The yolk is gradually absorbed as the animal increases in size (3-6). The life-history of a flat-fish (138: 5, 5^1) illustrates the "law of recapitulation." The young has an eye on each side, and rests vertically at first. Soon it rests on one side, and both eyes come to the upper surface. The mouth, tail, and chest-fins retain the original position. Its life-history suggests that flat-fish probably evolved from fish that swam in the usual way. Sole, plaice, flounder, and turbot are "flat-fish."

Fish are divided into three groups: Cartilaginous fish, having a skeleton of gristle (sharks, dog-fish, skates and rays). The hard durable teeth are often found fossil (166: 10). The rough skin ($137: 1^1$) bears many flat scales with enamel points. Bony fish, known by all, form the second group, and Dipnoi ("double-breathing") fish, the third group.

Dipnoi are connecting links between fish and amphibians. Though once numerous, only three kinds—the Queensland lung-fish, the Amazon lung-fish, and the African mud-fish—survive. The large Queensland Lung-fish—the Burnett River salmon—lives only in the Burnett and Mary Rivers. When the water is muddy, or foul with decaying vegetation, the lung-fish breathes air direct into the modified swim-bladder—a lung. The peculiar teeth of *Ceratodus* ("horny tooth") found fossil in North America, Europe, South Africa, and India, were known before the animal was found alive in Queensland in 1870.

CHAPTER XXII.

THE FROG: AN AMPHIBIAN.

A.—THE LIFE-HISTORY.

The life-history of the frog is of great interest. Since the shell-less egg has little food, the animal is easily observed during development.

The developing frog, like other animals, climbs its ancestral tree. Starting life as a single cell, the egg develops into a tadpole, which passes through fish and tailed amphibian stages, becoming a tailless amphibian. Land animals probably evolved from water animals; and here all the changes take place under our eyes.

The small eggs are laid in a jelly-mass—"frog spawn." It is interesting to note the uses of this jelly—to protect the eggs from enemies (including birds and fish), and the weather, sinking them in winter, and, by enclosing air bubbles, floating them in spring; to preserve them. (Eggs out of the jelly were destroyed by bacteria and fungi.)

The egg is one cell together with a food supply. The living black part grows round the yellow food, except at one spot, the yolk-plug.

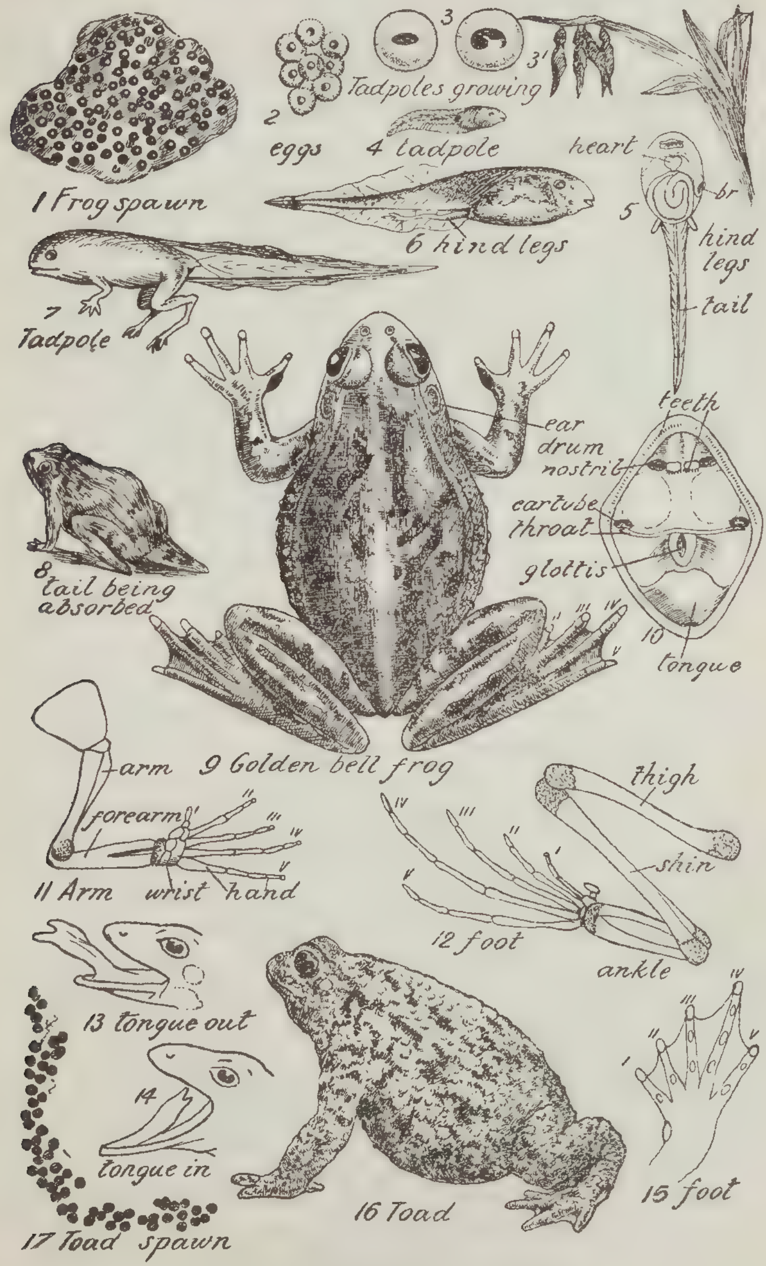


PLATE 139.—FROG AND TOAD.

The tail grows back (3). The animal jerks at intervals, and, leaving the jelly, attaches itself by a sucker to some weed, hanging (3^1), mouthless, blind, and uncertain. Having still some food, it does not eat for a time. It breathes by gills, at first on the outside. In Australian frogs the "external gill" stage is short or absent. Abbreviation is important in evolution; certain stages are shortened or omitted. The external gills shrink, and gill-slits form on the neck; blood-vessels form fringes round these. Water passes from the mouth through the gills. The tadpole is a fish as regards breathing, feeding, and moving. The horny jaws chew plants. If these are absent, tadpoles are cannibals. In a tadpole (5), with under surface towards you, notice in the red about the neck a white spot, the beating heart, appear and disappear. The heart, containing impure blood, has one auricle and one ventricle; it pumps the blood forward into fine vessels on the gills; the vessels re-uniting the blood runs backwards in the dorsal artery; the typical vertebrate circulation, forward on the under surface, up, and back beneath the backbone, then forward below to the heart.

Soon, buds grow into hind legs (5, 6); front legs form under the gill cover. One is thrust through the gill opening, the other tears through the cover. The four legs are perfect (7), and the tail is large.

Fish breathe by gills; reptiles, birds, and mammals, by lungs. Amphibians (*Amphi*, both; *bios*, life) are intermediate, breathing during life by both gills and lungs.

There are two main orders of Amphibians:—(1) Tailed amphibians (newts, salamanders, and a few other forms; these are absent from Australia). (2) Tailless amphibians —frogs and toads.

The tailed tadpole is a vegetarian water-liver, the carnivorous frog is a land-liver, breathing by lungs. Alterations are necessary to change tadpole into frog. The swim bladder changes into lungs, with blood-supply from the partly-divided, three-chambered heart; the alimentary canal is shortened. During reconstruction, the animal cannot feed, and the tail (8), a food reserve, is absorbed.

B.—THE ADULT FROG.

The head of the frog (139:9) is broad and triangular; the eye is the usual vertebrate eye (83:6), with golden iris. There are two eyelids—the upper thick and practically immovable; the lower thin and easily moved. Behind each eye is a smooth brown ear-drum. The frog has a wide mouth (139:10), literally "from ear to ear;" it swallows its food whole. The extensile tongue, fastened in front (10, 13, 14), is shot out at a fly, which adheres and is flicked into the mouth. On the upper jaw are fine teeth (10). The nose opens to the exterior by the two small nostrils (9:10); it opens also into the mouth,

The soft body is neckless, tailless, and without ribs. The frog swallows air, then gets it back into the mouth, and forces it out. The lungs being small, the loose, moist skin assists in breathing. Another use for the moist skin is to keep the animal cool; this suggests the water-bag, the wet rag on butter, and perspiration on man. Should the frog's temperature be considerably raised, it dies. The skin, which changes color, also hides the animal. The bright-green and golden bell frog becomes dark brown when hiding under a stone.

The front limb (11) is the usual vertebrate limb (152); the four fingers are webless; the thumb is absent. The jumping hind limb (139:12; 152) has an elongate ankle. The foot (15) has five webbed toes; the inner is shortest, and the fourth, longest. Fingers and toes of tree-frogs bear suckers. Such frogs can climb glass.

Miners and quarrymen sometimes find a frog in recently-blasted rock. The frog, alarmed by the explosion, probably crawled into the farthest crevice. The miner's "bed rock" was formed long ages before frogs were evolved. The quarryman's lava, once molten, would have reduced frogs to ashes. Occasionally a frog might crawl into a small hole and, growing, be unable to get out again. Using no food for warmth or work, it might live some weeks, but its early death would be certain.

The dry, clumsy, crawling toad (139:16) is carnivorous and toothless, and frequents water only to lay eggs in a string of jelly (17); its changes resemble the frog's.

CHAPTER XXIII.

REPTILES.

Reptiles—scaly, cold-blooded, air-breathers throughout life—are divided into four groups: lizards; snakes; turtles and tortoises (189: 18); and crocodiles and alligators.

Lizards usually have four legs with five fingers or toes, but some (140: 1) have no fore limbs and the hind limbs are mere flaps. Such are mistaken by many for very venomous snakes. The "slow-worm" of Great Britain is a "legless lizard." The only poisonous lizard (*Heloderma*) lives in Mexico. Lizards can be distinguished from snakes in four or five ways. Lizards, having eyelids (2), can close the eyes. Snakes, being without eyelids (3), have a "fascinating stare." The outer cover of the eye is shed complete with the snake-skin. Lizards have an ear-hole (2); snakes, though having the usual vertebrate auditory organ, have no external ear (3). Most lizards have a long tail (1); snakes have a short tail (6). Lizards have the under scales small like upper scales (1); most snakes have long transverse scales (6, 9) beneath the body. The tail may have one or two rows for the whole or part of its length. Many "legless lizards" have rudimentary flaps (1) for hind legs. Venomous snakes have no trace of limbs; non-venomous snakes (carpet snakes (Pythons)) have greatly reduced hind limbs (7). Snakes and monitor lizards have a forked tongue used as a feeler. The forbidding open mouth of the stumpy-tailed, blue-tongued lizard looks terrifying and assists in protection.

Having an incomplete double circulation, the blood is not fully oxygenated, and reptiles have a temperature about that of the air. They need no hair or feathers to conserve heat. In warm weather, the blood is warm and reptiles are active; in cold weather the blood is cold, and they are torpid and incapable of work. Usually reptiles have protecting scales or plates. In some lizards, the scales are reduced to granules.

In climbing *Geckoes,* the five fingers and toes have pads and claws. The much expanded tail may be discarded. The

tail wriggles and an enemy disposes of it; meanwhile, the lizard escapes. Another tail grows, but it is seldom symmetrical; it may branch into even five tails.

The large, usually vegetarian, iguanas are American. It is strange that two genera are found in Madagascar, and one in Fiji! None is found in Australia. The name iguana is wrongly applied by some to the large monitor lizards found in Africa (except Madagascar), Southern Asia, Australia and Tasmania.

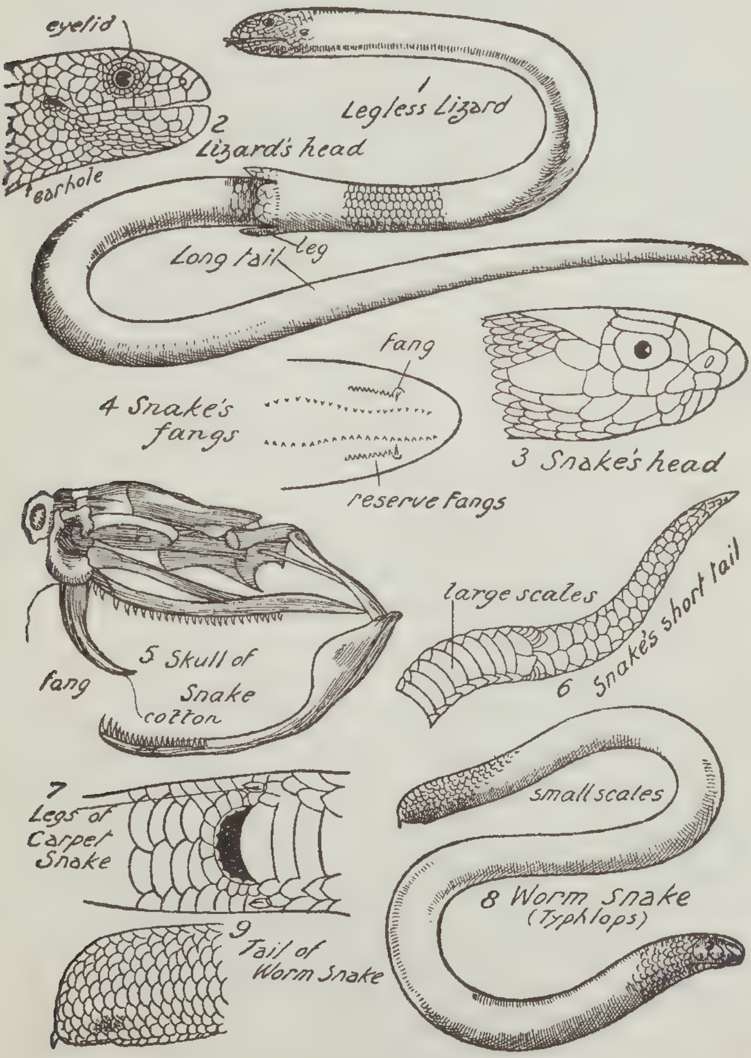


PLATE 140.—SNAKE AND LIZARD.

to match its surroundings is remarkable. Chameleons are found in Africa, Arabia, and India.

Australia has two crocodiles, but no alligators, which are confined to America and China. The skull of a crocodile has a rounded snout showing the big fourth lower tooth. In the alligator, this tooth fits in a pit in the upper jaw, and is invisible when the mouth is shut. The gavial is a harmless narrow-jawed form found in India. The so-called Gippsland crocodile is a water-frequenting lizard, *Physignathus*, found in the far east of Gippsland and north into Queensland.

Turtles are marine; tortoises (189: 18) are creatures of the land and fresh water. Edible turtles are common about tropical Australia. Hawksbill turtles have over the bony plates horny shields, yielding the tortoise-shell of commerce. Tortoises are found in Victoria, and are favorite pond animals.

CHAPTER XXIV.

THE BIRD.

A.—INTRODUCTORY.

"Bird study is no trifling fad. Our bird-life is a public property, protected by laws that are beginning to be respected and enforced." . . . "Birds are an asset whose value is being more highly appreciated each year," says Professor Hodge, in *Nature-study and Life*.

Study of living birds is desirable and pleasurable. Possibly, no other branch of nature so well aids one to achieve the purpose of nature-study. In bird-observing, a bird is seen; a halt is called until some distinguishing character is recognized; then a decision is made. Three important habits are exercised — waiting and watching for evidence; quick decision on obtaining evidence; self-reliance in depending on judgment based on evidence. Such habits are important to persons in any position in life.

Birds have been more studied than any other animals This is not surprising, for they are living, loving, active, graceful, and beautiful creatures. They "charm our ears

Reptiles have many pointed teeth (5), holding prey rather than chewing it. Most take live prey, though some eat carrion. Having the skull-bones (5) loosely attached, snakes can swallow large animals. The recurved teeth of one side grip; the other side is worked forward, and the teeth inserted; then the first side is advanced, and so on. A snake really gets outside its prey. If two snakes seize the same animal, there may be trouble. One python has pulled itself over another, the inner one was digested. Snakes do not slobber their prey. A poison fang (5) is a modified tooth. In whip-snakes, the poison-groove is open. In most venomous snakes, it is practically closed. The diagram shows a cotton thread in the poison canal, opening some distance back. If it opened at the point it would be plugged by flesh or the weakened point would break. The hypodermic syringe needles are made on the same plan as the snake's fang. Two fangs are functional at one time. If damaged, reserve fangs replace them. Australian snakes have short fangs. If they bite through clothing, probably little poison enters the flesh. Sometimes a snake, having bitten something earlier, has not enough poison for serious harm from a second bite. Snakes do not swallow their young for protection. If a young one passes down the throat, it is digested. Before birth, young snakes are in the body-cavity, not the stomach.

The burrowing worm snake, *Typhlops* (140: 8), has a burrowing nose, eyes beneath the skin, mouth underneath, a spine on the short tail acting as a fulcrum when the animal is crawling, and small, polished scales above and below. It feeds on ants and cannot open the mouth to bite.

Lizards moult in pieces; a snake moults the skin entire. It passes through a narrow place, catching the skin in something, and turning it back as a glove-finger is turned inside out. It is shed complete, even to the eye covering.

Most lizards lay soft eggs (89: 13); most venomous snakes produce live young; the brown snake, however, lays eggs. The river tortoise lays hard-shelled oval eggs.

The chameleon is a famous lizard with long prehensile tail. The long, round sticky tongue is shot out suddenly at an insect. The chameleon's power of changing color

with such melody, or startle them with the utterance of articulate speech."

On account of their size, birds are easily observed. Because of their powers of flight, they hide less than many other animals. Their family life is easily watched; their care of their young is remarkable, and the skill with which they build their nests is wonderful. As birds are acceptable food, man early studied their ways. Probably, the domestication of birds helped man greatly towards civilization.

Birds are found the world over. Even the frozen south is inhabited by numerous birds. Swamp and sea, ocean and oasis, plain and prairie, riverside and range, shore and snowfield, mountain and meadow—all have their birds.

Most people declare they know little about birds, but almost everyone can recognize a pigeon, a waterhen, a seagull, an ibis, a duck, a cormorant, a hawk, an owl, a parrot, a lyrebird, and a swallow, thus recognizing representatives of more than half the orders of Australian birds. As each knows emu, penguin, quail, and plover, that accounts for three-quarters of the 21 orders of Australian birds.

Of the 19,000 species of birds listed by the late Dr. Sharpe in his *Handlist of Birds* (5 vols.), two-thirds came in the last order, the Perchers. The one-third, divided into 35 orders, are usually quite easily recognized. There is difficulty in dividing the Perchers into families which do not overlap. However, since closely-related birds do not often live together, it is easy, usually, to recognize individuals. It would be difficult to pick out the characters that place starling and common (Indian) myna in the one family, but it is easy to recognize each individually. Even amongst Perchers, all know swallow, robin, willie-wagtail, thrush, blue-wren, Australian magpie, magpie-lark (mud-lark), ground lark (pipit), sparrow, and crow as individuals. It is a rich bird locality that shows 120 kinds of birds in one year. Of these, probably not more than 80 would be seen by the ordinary observer, and of the 80 at least three-quarters would be known (though perhaps not by the recognized venacular name) to practically everyone. People should realize that bird-study is one of the easiest of studies, largely because, being favorite objects

of observation for ages past, much is known about them. Be satisfied to recognize seven kinds of birds, next week you will know eight, and you will soon know most of the birds to be met in your locality. At least you will gradually separate those you do not know, and then the easily-accessible literature regarding birds will enable you to recognize them definitely. The one necessity is the use of the exact vernacular name every time you speak of a bird.

B.—THE BIRDS OF AUSTRALIA.—A STUDY IN CLASSIFICATION.

Birds, forming the class *Aves,* are feathered chordate (vertebrate) animals. The class is usually divided into two sub-classes according to the character of the breast-bone. Emus (141 : 1) and other large running birds having no need of big muscles to work the small wings have no ridge of bone (keel) on the raft-like breast-bone; these Ratite birds formed the first sub-class *Ratitae* (rata, a raft). Five southern families of living birds are included in this sub-class—the Kiwi (New Zealand), Emu and Cassowary (Australia), Ostrich (Africa, and up to Palestine and Arabia), and the Rhea (South America); all are flightless, and all are southern; an evidence of a previous great southern land mass now broken up. Emu, "the most primitive of living birds," and Cassowary form the first order of Australian birds.

The remaining birds have a keel (143) on the breast-bone for the attachment of the big wing-muscles. These are grouped as Carinatæ (*carina,* a keel). The Australian members of this sub-class are divided into 20 orders.

The scratchers (141 : II.), including domestic poultry, form order 2. Fowls are descended from the wild jungle-fowl of Asia. Guinea-fowls live native in Africa, and turkeys in North America. Gaudy pheasants are absent from Australia, though quail (II.) belong to the pheasant family. The mound-builders (150 : 13) are the most interesting members of the order. The small button quail (III.), with no hind toe, are placed in order III.

Pigeons (IV.) and doves, "cooers," come next. Almost three-quarters of the known kinds of wild pigeons are restricted to the Australian region. The crested heads of the crowned pigeons of New Guinea are sometimes worn in women's hats.

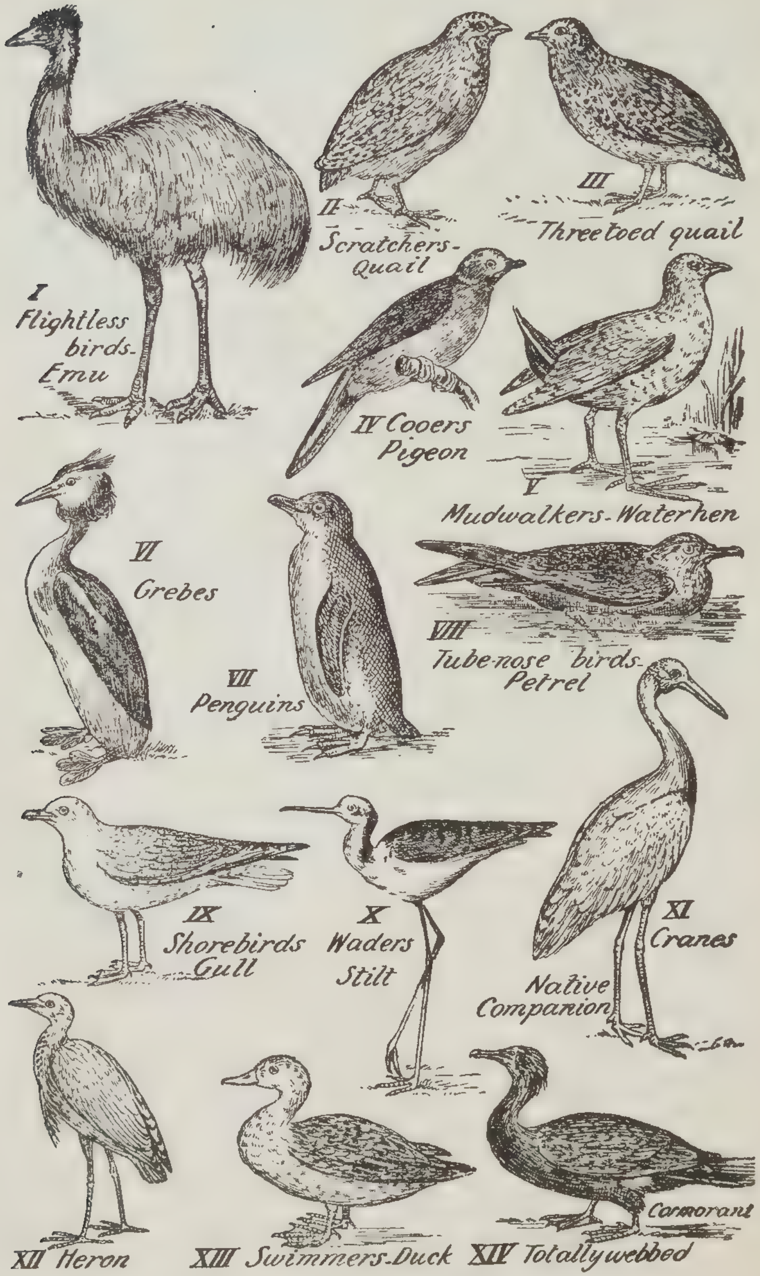


PLATE 141.—AUSTRALIAN BIRDS IN ORDERS.

Long-toed Mudwalkers (V.), land-rails, water-rails, and water-hens are cosmopolitan The British moorhen is represented by our common dark moorhen, or water-hen (V.). The long toes (146: 5) serve well for walking over soft mud or swamp vegetation.

PLATE 142.—AUSTRALIAN BIRDS IN ORDERS.

Grebes (order VI.) are also cosmopolitan. The great crested grebe and the dabchick are common species spread widely throughout the Old World. They have lobed toes (146:4), and are marvellously quick divers. Though a poor walker and flier, the crested grebe (141: VI.) is found from Great Britain to New Zealand.

Penguins (141:7; 147:13), remarkable southern birds, are found up the Pacific Ocean to the equator (Galapagos Is.), but not into the Atlantic Ocean or Indian Ocean. Their distribution supports the geographer when he says the Pacific Ocean is an ancient ocean, but the Atlantic and Indian were much more recently formed.

Order VIII. consists of Ocean Birds. The northern Hemisphere is the land, the southern, the water hemisphere.

These true ocean dwellers are typically southern birds. All are easily recognized by the tube-nose. Storm petrels, Mother Carey's chickens, birds of the wild storm, were disliked by sailors. Mutton-birds, petrels (141: VIII.; 145: 12), occupy miles of nests on Phillip Island, Victoria. They yield a yearly harvest to the remarkable Cape Barren islanders. Albatrosses (147:2), flying round ships without flapping the wings, nest on lonely rocks. They are found throughout the Pacific, but, except by accident, not in the Atlantic Ocean north of 25deg. S. lat.

Shore-birds, gulls, terns, and skuas (sea-pirates) form Order IX. Silver gulls (IX.), following irrigation channels, are found far inland. Some terns (147:7) are freshwater birds, and, with gulls (IX.), may follow the plough for grubs and worms.

Order X., Waders, forms a most interesting collection, modified for life about swamps, plains, and beaches. Thirty-five of the forty-four Australian waders breed in Siberia. In spring, when the ice-sheet, a great, natural freezing-chamber, liberates its supply of preserved fruits, and animal food, these birds flock from all quarters of the globe into the far north, where the midnight sun ripens fruits of shrubs in great abundance, and where myriads of insects breed in the great swamps on the tundras. The birds are said to take a fortnight to travel to Siberia from Australia.

Order XI. — The true cranes include our Australian crane, the native companion (141: XI.), the only crane

found in Australia. It is remarkable how often Australia has one of a group common elsewhere; one crane, one roller, one bee-eater, one stork (Jabiru), and others.

Order XII. includes herons (XII.), ibises, bitterns, and spoonbills. Living under somewhat similar conditions, herons resemble cranes externally, but they are not closely related to them. The beautiful white egrets (149: 16), in the breeding season, bear delicate plumes on neck and back. Unfortunately some women, thinking they need ornament, are responsible for barbaric cruelty in causing the death of adults and young. Ibises, embalmed by the Egyptians, are recognised here also as birds of great value.

Large swimming birds, swans, geese, and ducks form Order XIII. The black swan is a unique Australian bird.

Cormorants, pelicans, and related birds in Order XIV. have the four toes (146: 13) webbed instead of three, as in ducks (146: 14). All range widely over the earth.

Order XV.—Diurnal Birds of Prey (142: 15; 144) are practically cosmopolitan. The Australian wedge-tailed eagle is the king of his tribe. Hawks are valuable birds, but a few have a bad name often undeserved. There is indiscriminate slaughter of innocent and guilty.

Owls—Noctural Birds of Prey, form Order XVI. The Australian Barn Owl is identical with the European bird. The Boobook Owl was once thought to be a cuckoo calling at night in this land of upside-downs. It calls mopoke, morepork, cuckoo, or boobook, as the hearer fancies.

Parrots and Cockatoos (XVII.) are characteristic Australian birds. Two toes in front (146: 2) and two behind form a "climbing foot." Cockatoos, except one kind in the Philippine Islands, are restricted to the Australian region.

Order XVIII. is a "carpet bag," including many birds that are not closely related. The remarkable Frogmouth (Mopoke), with wide gape; the rolling Dollar-bird, the Australian roller (147: 9), the rainbow-colored bee-eater, the Laughing Kingfisher (142: XVIII.b), the jolliest of birds; Nightjar, goatsucker (142: XVIII.a), swift (147: 4) and humming-bird (American) are placed here.

Cuckoos are granted rank as an order (XIX.). Like parrots, they have two toes in front and two behind. The one British cuckoo calls "cuckoo." Some of our fourteen

Australian cuckoos are more common, more noisy, and more persistent, yet few recognize them as cuckoos. The pallid cuckoo, running up a chromatic scale, sometimes calls all night. Australian cuckoos have the parasitic habits of the Old World birds. One Australian cuckoo builds its own nest, and rears its own young, so do American cuckoos, where cowbirds are the parasites.

Well does the Lyre-bird deserve Order XX. to itself. Its tail (148:8), its marvellous power of mimicry, and its interesting life render it a unique bird.

In Order XXI., come the numerous Perchers, divided into Songless Perching Birds and Song-birds. There are not fewer than forty-nine families of song-birds. Australia has more than its full share of these. Here we can mention only five Perchers.

Swallows (a) are cosmopolitan; our Welcome Swallow is the counterpart of the European House Swallow. Our grey thrush (b), named *harmonica* by a British ornithologist, deserves its specific title. The rich, full note is not so continuous, but is richer than the notes of the European song thrush. The bare, black-headed friar bird (c), often calls "tobacco-box," or "four-o'clock." These noisy birds are honey-eaters, the characteristic Australian family.

The fine Australian magpie (d), the "white crow that sings," is the "piping crow-shrike" of early writers. It is a famous singer, and a showy, useful bird. The bower-bird (e) is "without exception the most remarkable bird" found in the world. Its bower—a playhouse—is distinct from the nest.

In a similar review of resident British birds, 4 orders, emu, penguin, parrot, and lyre-bird, would be omitted, while four others—sand grouse, true divers, auks, and woodpeckers—would be added. Birds, that is the widely-spread ones, are remarkably uniform the world over. Australia has "every widely-spread family of birds but two." Therefore know the birds of your locality, and you will know generally a fair percentage of the birds of any locality.

C.—BIRD STRUCTURES.

The body of a bird is a double cone, or egg-shape, with a close, smooth coating of feathers, offering little resistance to the air. The center of gravity is low. The large wing

muscles are fastened to the breast-bone (143: keel); those of the leg are close to the body, with long tendons reaching the toes. The weight is concentrated.

The domestic fowl (143) shows the following parts:—head, body, neck, joining head and body, wings, and legs. The head is concerned with sense organs and food-getting, the most pressing and frequently-recurring need of life.

The fowl sees an object with one eye. We have two-eye vision; birds, except owls, which have eyes directed forward, have one-eye vision. A bird's eye is more perfect than ours. The soaring eagle (147: 8) suddenly drops and seizes a small animal seen from aloft. When did the eye change from a "long-vision" to a "close-vision" eye? Similarly, a bird flies swiftly into a tree, and perches there.

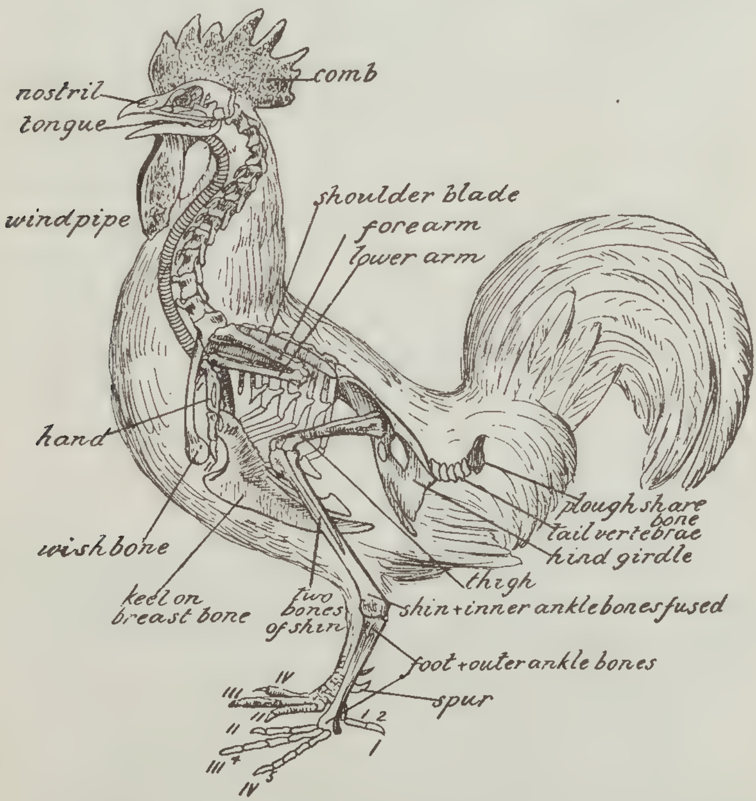


PLATE 143.—A DOMESTIC FOWL, TO ILLUSTRATE THE STRUCTURE OF A BIRD.

When did it first see the branch? How did it judge the distance? A startled bird darts through thick brush as though nothing were there. The eye, with a bony ring assisting in altering the shape of the lens, can be adjusted quickly. The bird closes its eye mainly by raising the lower lid. The eye is protected from dust and injury by a third eyelid (144), the "nictitating membrane," which is represented in man by the red, fleshy cushion in the corner of the eye. This membrane often crosses a fowl's eye. Many birds see well at night, and most migratory flights are taken then.

The sense of smell seems unimportant to birds. The fowl's nostrils are two slits in the horny beak; hawks (144) and parrots (145: 18) have the nostrils in a soft skin (cere).

The tongue, often horny, varies in size. It is longest and stickiest in some woodpeckers, which gather prey with a flick of the tongue. It is a brush in honeyeaters (145: 19; 142: XXI.c) and lorikeets; it is reduced in ibis, spoonbill, kingfisher (142: XVIII.b), and pelican (145: 6). Soft-tongued parrots (142: XVII.a) and cockatoos (b) probably have well-developed taste. Birds, avoiding brightly-colored caterpillars and butterflies, must have some power of taste, a sense said to be poorly developed in birds. Some birds use saliva to cement together the nest materials. Some swifts found from Malaysia to Queensland make nests of saliva, the "edible swallows' nest" of commerce.

Birds have good hearing; geese are better watchers than dogs. Who has not heard of the geese that saved the Capitol? The external ear is absent, except, perhaps, in "horned owls," which are not represented in Australia. The emu's ear-hole (83: 16) is visible.

The sense of touch is well developed; the bases of the feathers being supplied with nerves. A bird is alarmed at the lightest touch. An appreciation of color and beauty is shown by the bower-birds (142: XXI.e) of Australia, which decorate the play-bower with pretty objects.

The head sometimes bears a crest, which may show emotion. Resentful, sentinel - posting cockatoos (142: XVII.b), disturbed from a maize crop, raise the crest and screech angrily. Beebe, an American ornithologist, thought an excited pink cockatoo "a wonderful sight."

A bird's hind limbs (143) support the body. The structures on which the legs work have grown solidly to the backbone (143). A bird cannot bend its back. The neck enables the bill to reach every part of the bird. We have oil-glands to keep the skin in order. Most birds have one "oil-gland" at the upper base of the tail. The bill takes the oil and dresses each feather. The oil-gland is especially important to water-birds, which spend much time oiling their feathers. When legs are long, necks are long, enabling birds to pick up food easily. Swans have long necks, but short legs, a feature associated with their habits of feeding on grass growing in shallow waters.

A bird's lungs open into air-sacs in the body, and big bones; all the air in the lungs is changed with each breath. While man breathes from 13 to 16 times a minute, birds breathe from 20 to 60 times a minute. The blood is better oxygenated, and the body temperature is higher than with other animals. The temperature varies from about 100

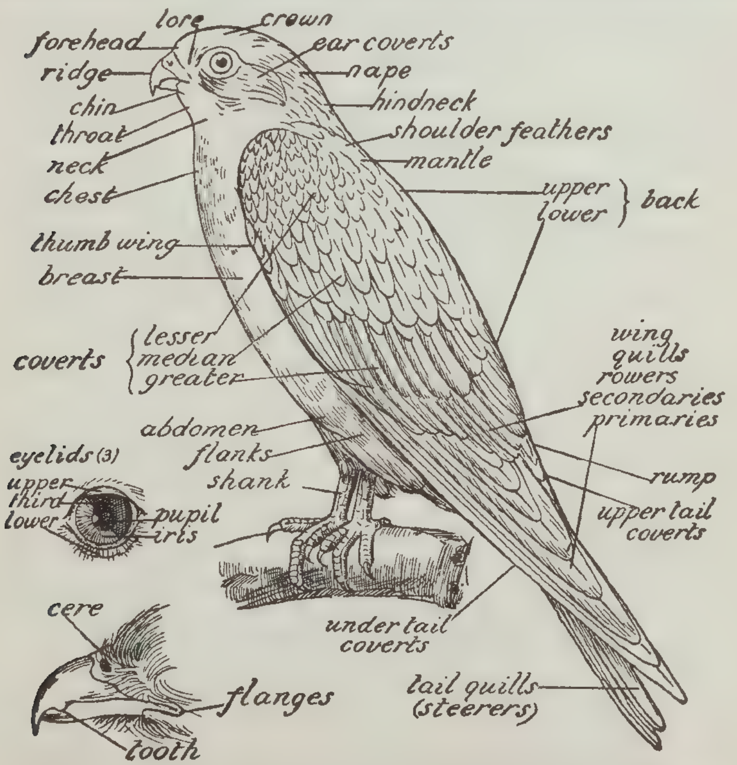


Plate 144.—A KESTREL, TO ILLUSTRATE THE TOPOGRAPHY OF A BIRD.

deg. F. in some incubating birds to 112deg. F. Our temperature is normally 98.4deg. F. With hot, well-oxygenated blood, birds live at a high pitch. The supply is more frequent than with us. The heart is said to "beat 120 times a minute in resting birds, double that when flying, and at a rate that cannot be counted when excited." Birds often die of fright. Sportsmen sometimes gather birds that show no mark of shot.

Bird lovers have a definite series of names for the different parts of a bird. The illustration of a kestrel (144) fully labelled shows the "topography" of a bird.

The voice of birds is produced by a special apparatus. Our voice-box (larynx) is in the throat; the bird has a larynx in the upper throat; it has also a "syrinx" (88:8), best developed in "song-birds," at the lower end of the wind-pipe. Most birds have many notes. Alarm notes, like the "kiss, kiss" of the blackbird, and the "chick" of the greenie, warn mates and other birds. The mate usually answers the call note at once, and there is the song distinct from these. Many birds mimic others. When you can recognize the songs of five birds, you will soon know those of six and ten. Name the bird when you hear the call.

Different birds attend to "personal cleanliness" in different ways. The fowl enjoys its dustbath as the horse does a roll. A good shake dislodges dust and probably parasites. Starlings and thrushes get under a lawn sprinkler. Sparrows enjoy bathing in gutter or pool, and seem just as fond of a dustbath. Most birds spend time "preening" their feathers.

The "showing off" displays of birds in the spring are entertaining. Most birds have some display. Even that street larrikin, the house-sparrow, has lost the grey tips of the throat feathers, and wears a black cravat. He partly spreads his wings, throws out his chest, and tries to charm his mate. Peacocks (149:14) and turkey gobblers are conspicuous when displaying. Little is known of the displays of Australian birds, but the unique bower (142:XXI.e) of bower-birds and the dancing mounds of lyre-birds are amongst the most remarkable of bird structures. There is still much to learn in Australia concerning this delightful branch of bird-lore.

An Australian Shrike-Robin.

The food of grain-eating birds is softened in a crop, and passed to the gizzard—a muscular organ lined with a rough skin, where it is ground up Fowls pick up small gravel and sand, which help to grind the food. The inner cells of the crop of pigeons produce a curdy material, "pigeon's milk," on which the young are fed. Birds, especially insect-eaters, eat more food in proportion to their bulk than other animals. Being practically insatiable, they destroy myriads of insects. It has been calculated that, if bird-life ceased, plant life, and therefore human life, would cease too. Pests, like Aphids, grasshoppers, and other insects, now held in check, would upset the balance of nature and destroy our food supply.

Truly birds, with their almost inexhaustible capacity for food, are required. No wonder the cry has arisen that we should save our birds. Some think birds are in little danger of extermination, but the case of the great auk should give us pause. The passenger pigeon, of the United States, is an even more striking case. Wilson, the American ornithologist, estimated that one flock of these pigeons contained 2230 million birds.

"Bird Lore" contained a photograph of the last known Passenger Pigeon. It died on September 30th, 1914. Already the night or spinifex parrot has, it is feared, become extinct in Australia.

D.—BILLS OR BEAKS.

Bills (145), mounted on flexible necks, and varying in size, shape, and texture, serve many purposes. They rival hands as grasping organs, and tools. They are used chiefly in connexion with food-getting. The fowl's bill (143) picks up and breaks off food and bites grass. The flattened bill of the oyster-catcher (145: 14) is a pickaxe, prising open oyster and mussel-shells. It is a lengthened, sensitive probe, discovering food in soft mud for snipe (145: 16), and godwit, which can open the flexible bill to seize their prey; the arch several inches long of ibis and curlew (145: 10) explores crevices or probes soft mud. The bill of the avocet (145: 11) is a delicate, upturned scoop. In the plover-like wading birds, the various bills have been compared to a "complete set of surgical instruments," cul-

minating in the side-bent bill of the New Zealand wry-bill plover, which edges its prey out from under stones. Each wader secures food in a special way, and competition between them is less; more birds live on a given area.

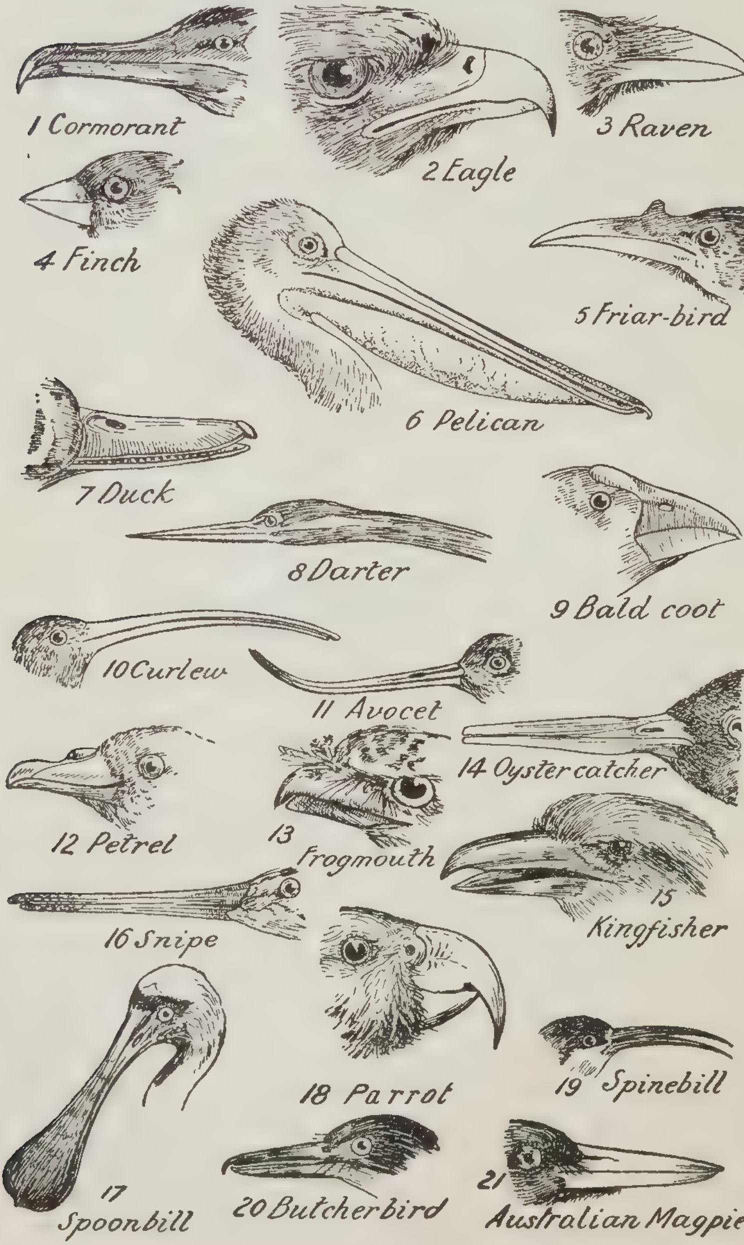


PLATE 145.—BEAKS OF BIRDS.

The bill is a tearing organ in eagle (145:2) and hovering kestrel; a climbing and shredding tool for parrots (145:18) and cockatoos; a carrion-tearer for strong-billed ravens (145:3) and vultures; a needle for tailor-bird and fantail-warblers; a shuttle for weaver-finches (145:4); a wood-tearing organ for black cockatoos obtaining wood-boring larvæ; a digging instrument for white cockatoos (142:XVII.b), ploughing the ground for bulbs and grasshoppers' eggs; a wide-open fly-trap for swifts (147:4), hunting in upper air, swallows (142:21) in mid-air, and frogmouths (145:13) and nightjars hunting silently by night; a fish-catcher for cormorants (141:XIV.; 145:1) pursuing fish under the water, gannets diving deep from aloft, and terns (147:7) diving shallow for small fry; a fine-toothed fish-spear for the darter (145:8); a fine brush for honeyeaters and screeching lorikeets, brushing honey from eucalypt flowers; a sieve for ducks (145:7), straining food from mud; a ladle for spattering spoonbills (145:17); a hooked insect piercer for flycatcher and butcher-bird (145:20); a seed-shelling organ for sparrows (147:5); a mortising chisel for woodpeckers; an awl for tit-warblers and blue wren-warblers, working long hours in suburban gardens and orchards; a fish-basket for pelicans (145:6), working in company and driving fish into the shallows; a digging organ for white-backed magpies (145:21), seeking for grubs; a mud-spreading trowel for nesting swallows; a tunnelling organ for diamond birds and bee-eaters; an ornament for bald-coots (145:9), where a horny plate covers the forehead; possibly also an ornament for the fruit-eating friar-bird (142:XXI.c), with hump on the bill; an organ of transport for most birds (hawks and eagles carry food and nesting material with the feet).

No living bird has teeth, though some extinct birds had.

E.—LEGS AND FEET.

Legs and feet (143; 146; 152:B5) have many modifications that adapt a bird to its mode of life. The thigh (143) being short, the forward-bending knee is hidden in the feathers. The bird's shin is long, and contains, as usual, two bones, one of which is thin. The first row of ankle-bones is fused with the shin bone. The muscles are gath-

ered mainly at its upper end. The apparent knee is the ankle, for birds walk on the length of the toes as cats and dogs do. Three foot-bones fused with the further ankle-bones form the "cannon-bone" (143: 152), with three rounded structures, bearing three toes. The small first foot-bone (143), bearing the first (hind) toe is free.

Most birds have four toes; some ground-dwelling birds have three (146: 1; 141: 1), the first being absent. The

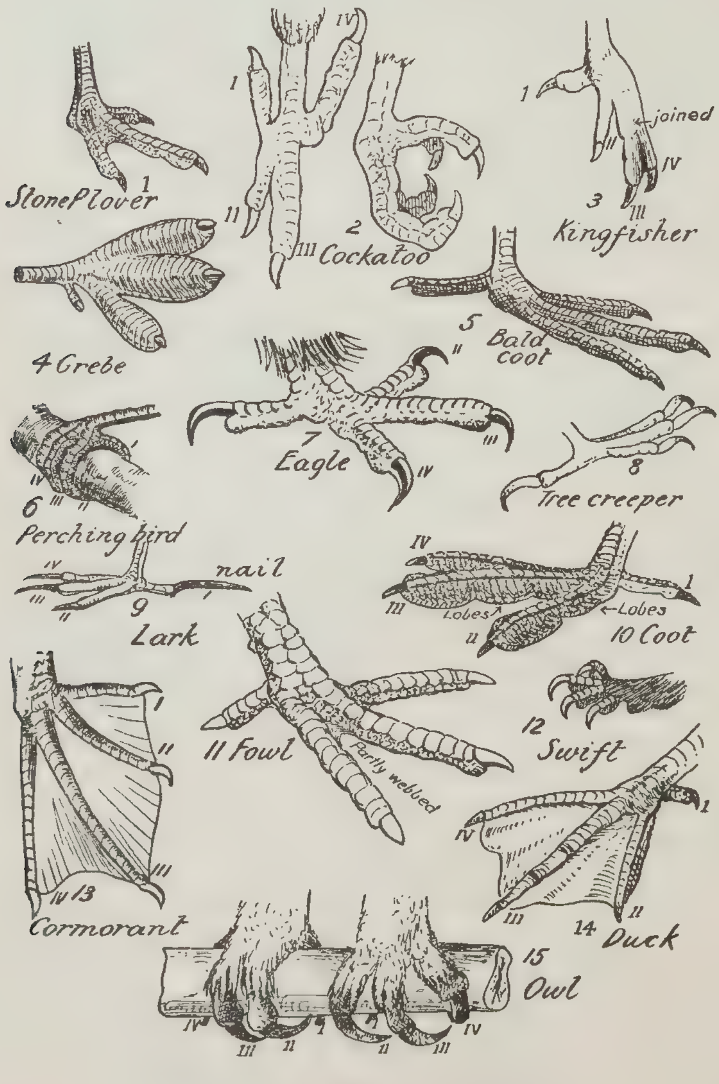


PLATE 146.—FEET OF BIRDS

ostrich alone has two toes. The hind-toe represents our big toe. It is large and important in perching birds (146: 6, 8, 9), and birds of prey (146: 7); it is small and raised in fowl (143) and duck (146: 14). The fifth toe is absent in birds. The number of joints in birds' toes is usually one more than the number of the toe. The hind (first) toe has two joints (143); the second, three; the third, four; and the fourth toe has five (143) joints. The first toe is called the "hind toe," the second the index, the third the middle toe, the fourth the ring toe; the toes, except the first, have the same names as the fingers; index, middle, and ring toes for second, third and fourth toes, respectively. In the large swimmers—swans, geese, and ducks, as well as ocean birds and gulls—three toes (146: 14) are webbed, the hind toe being free. In the totally-webbed swimmers (cormorants (146: 13), and their allies), the four toes are webbed.

Fowls (146: 11) have a small web. Coots (146: 10) and grebes (146: 4) have lobes of skin along the sides of the toes. Many swimmers, water-hens and baldcoots, have long, thin, webless toes (146: 5). Usually, the toes end in a claw. These claws are long, sharp, and curved talons in Birds of Prey (146: 7); such birds kill their prey with their feet. The fowl (146: 11) has blunt claws that scratch rubbish aside to expose any food. Cuckoos, parrots and cockatoos (146: 2), with two toes in front and two behind, are "yoke-footed" birds. Owls (146: 15) and osprey (fish-hawks) can reverse the fourth toe, having two in front or three in front. To have two toes before and two behind is a good arrangement for climbing parrots, though tree-creepers (146: 8)—constant climbers—have three toes in front and one, with a strong claw, behind. In larks (146: 9), the hind claw is sometimes very long. Kingfishers (146: 3) have the third and fourth toes partly united; a "syndactylous foot," suggesting that of the kangaroo (152: 4). Some swifts (146: 12) have the four toes directed forward.

The foot has many uses. It catches fish for fish-hawks and fishing-owls; burrows for burrowing-owls; catches and kills animals for eagles and falcons; catches insects and mice for kestrels and kites; carries sticks for the nest of

birds of prey; travels on soft mud and floating plants in long-toed water-hens (146: 5; 141: V.); heaps up the egg-mound (150: 13) for mallee-fowls and brush turkeys; protects birds which lie on the back to defend themselves with beak and claw; steers the penguin (147: 13); fights for fowls (143) and peacocks; holds food for parrots, cockatoos (146: 2), and baldcoots; and occasionally preens feathers for cockatoos, which have powder-down and no oil-gland.

A perching bird cannot fall off its perch. If the legs are bent, the toes (146: 6) are closed tightly. When a fowl straightens its leg, the toes are straight.

The "cannon-bone"—the so-called "tarsus"—is often covered with small brightly colored scales or plates; occasionally it is feathered.

F.—WINGS.

A bird is adapted for flight. In man, the front limb is a grasping organ. In most animals the front limb assists in supporting the body. Not so in birds, where the front limb (147: 1; 143) is modified for flight. The wing has three parts—upper-arm, fore-arm, and hand. The hand is profoundly modified into a stiff rod, to which the flight feathers are lashed. The hand has the further row of wrist-bones fused with it, and carries three fingers — thumb, index finger, and middle finger, the fourth and fifth fingers being absent. The separate thumb bears the small false wing (147: 1) and a claw. The fore-arm bears some flight feathers (secondaries), eleven in crows and up to forty in albatrosses. The hand bears the main flight feathers (primaries), ten in magpies and crows. Often the last primary is small. Birds close the hand to the outer side of the fore-arm.

The shape of the wing is connected with the mode of flight. Some birds, quail (141: II.), have rounded, curved wings, suitable for a sudden short flight to escape immediate danger. They make a whirring noise, which, startling an enemy, gains time for escape. Pigeons make a sharp clap when starting suddenly. Terns (147: 7), swallows (142: XXI.), some hawks (144), and swifts (147: 4) have long, pointed, narrow wings, as most rapid fliers have. The Albatross (147: 2), with long soaring wings, seldom flaps

them. Many birds (ibis) flap a few times, then soar; others, sparrows (147:5), open and close their wings continually. Herons (blue cranes) and night herons (147:3) row themselves along, flapping lazily. Hovering kestrels (144) move their wings quickly. Eagles (147:8) soar grandly; kites are varied fliers; toy kites were made in imitation of the flight of this once common bird. Tradition says "hawks kill chickens," so every bird of prey, even insect-eating kestrels and fish-eating sea-eagles, are foolishly killed. Numerous kites once acted as scavengers in London. There is none there now. Skylarks soar at heaven's gate.

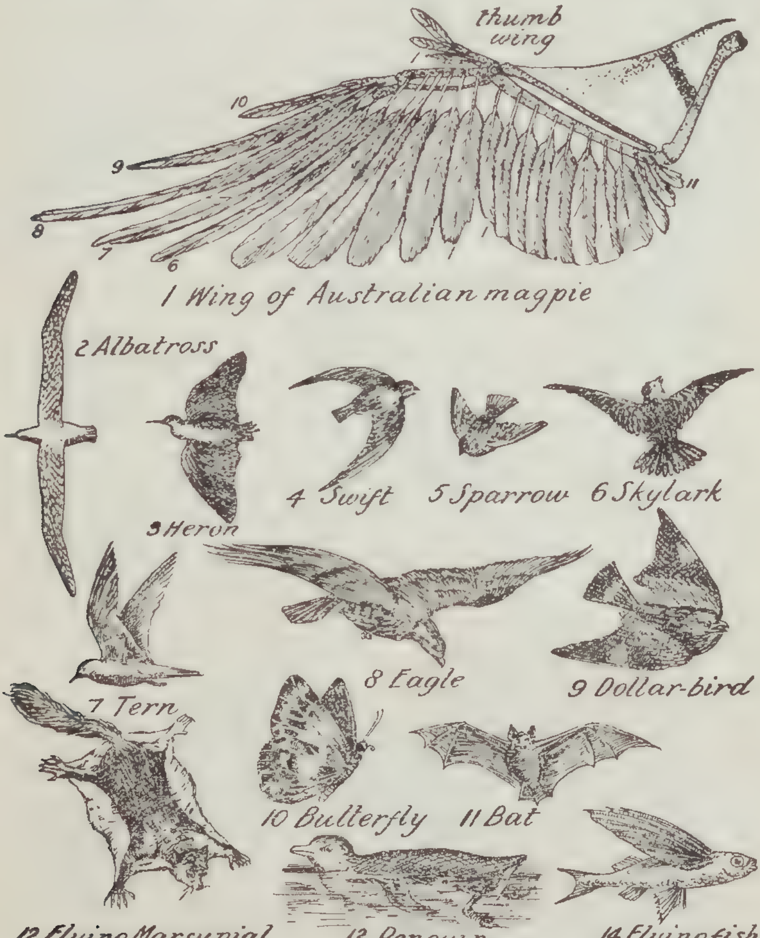


PLATE 147.—WING AND FLIGHT.
1, 10-1, Primaries; 1-11, Secondaries.

The penguin (147:13) flies under water with flattened paddles. Spurwing plovers and some other birds have strong bony spurs on the wings. Swan and gander may use the wing to thrash an intruder. The hen uses her wings as a shelter for the chickens, and most birds like to snuggle the head behind the wing when asleep.

Firm attachment is needed for the powerful muscles that work the wing. The big muscles that pull down the wings are attached to the keel and the breast-bone. Smaller muscles working on a pulley raise the wings; these are also attached to keel and breast-bone below. The shoulder girdle is firmly fixed to the body. The shoulder-blade bones (143) are long and bayonet-like, and are strapped along the ribs. The collar-bones meet and form the merry-thought bone or wish-bone, thus helping to give a firm shoulder-joint for the wing to work on.

Other animals also possess the power of flight. Insects and bats are true flyers. Flying squirrels glide (volplane) downwards; the flying-fish (147) travels possibly two hundred feet through the air.

G.—TAILS OF BIRDS.

Birds' tails are various. In the oldest known fossil bird —*Archaeopteryx*—the tail was lizard-like and long, with two feathers at each tail-joint. No modern bird has a long bony tail. The number of vertebræ is much reduced, and the last joints have fused to form the "ploughshare bone" (143). This bears tail-feathers—"steerers"—arranged fan-wise about it. Magpies and crows have twelve tail-feathers, The number varies from six in emu-wrens (148:2) to forty in fan-tailed pigeons. In the emu (148:10), there is no ploughshare-bone; emu and grebe have no tail feathers.

The tail may be short (quail) (148:6), square (square-tailed cuckoo), rounded (coachwhip-bird and the Indian turtle-dove), forked (swallows and terns) (148:4; 147:7), or wedge-shaped (Australian eagle) (142:XV.). Often tails (148:3) are tipped white, usually the two middle feathers are not white. When folded, the tail is not conspicuous; open, it "warns" mates to fly. Sometimes, the outer feather is white, as in the Australian pipit, "Jacky Winter," and spinebill; possibly this is a case of "recogni-

tion coloration," or possibly "warning coloration." The tail is a rudder, and also serves as a brake. Flying pigeons, gulls (153: 3), or magpies, when wishing to alight, press the tail downwards against the air, to reduce the speed. Birds often use the tail as a prop. A sparrow sometimes rests on a wall; the tail being pressed tightly against it. This use of the tail reaches its extreme in the spine-tail swift (148: 1, 153: 5). The short, stiff tail feathers end

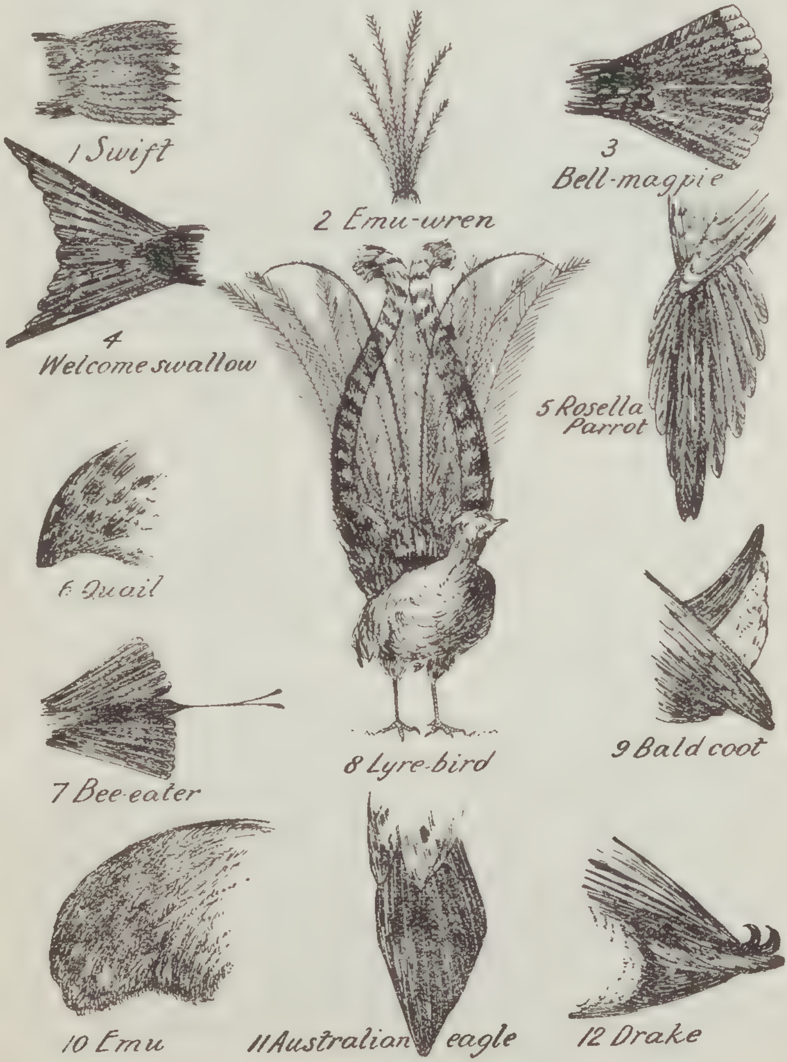


PLATE 148.—TAILS OF BIRDS.

in spines, that assist the bird in clinging. Beebe placed young swifts on a vertical, glazed surface; they did not slip. Woodpeckers, absent from Australia, use the tail as a support while chiselling a hole to obtain food or to form a nesting hollow. The tree-creeper, common in most countries, is said to use its tail as a prop.

The familiar Willie Wagtail, a fly-catcher, swings its tail from side to side, it is not in any way related to the European wagtail, a member of the pipit family. The blue wren-warbler carries the tail erect. The erect tail of the emu-wren (148: 2) has only six feathers, each bearing a few barbs, which are not hooked together; these suggest emu feathers. The jerking of the tail of bald-coots (148: 9) and sandpipers is often seen. Many tails may be white at the side (moor-hen), or under the tail (bald-coot), possibly "warning coloration." The bee-eater (148: 7) has two long tail feathers bare of barbs for some distance. The American motmot is said to produce a similar tail ornament by removing the barbs with its bill. Skuas have two tail feathers longer than the rest. Most parrots have a short tail, but the long-tailed rosella (148: 5) and its relatives form a sub-family of parrots—the broad tails—restricted to the Australian region. The male lyre-bird's tail (148: 8) has two partly-webbed and two fully-webbed feathers; the latter are beautifully marked, and form the sides of the lyre. The twelve wire-like feathers are lightly webbed. This ornament is used when the bird is dancing on the mound, and "showing off" to his mates.

H.—FEATHERS AND COLOR.

A feather is the peculiar bird structure. "A bird is a feathered animal"—a good definition.

Feathers, amongst the lightest, warmest, and strongest of animal substances, are marvellously perfect in their millions of details. Dr. Newton records a crane's wing-feather with 650 barbs (main branches) on the inner web, each containing about 600 pairs of radii (barbules). As each bore possibly a dozen barbicels (hooks and cilia) there may have been 10,000,000 definite structures on one web.

The arrangement for rigidity, so that the plumage may be air-proof and yet allow free movement, is marvellous.

The backwardly-directed radii (149: 11) are bent over along the top edge; the hooks of the other set (149: 10) catch under this edge and slide along it, securing a perfect air-resisting down-beating structure.

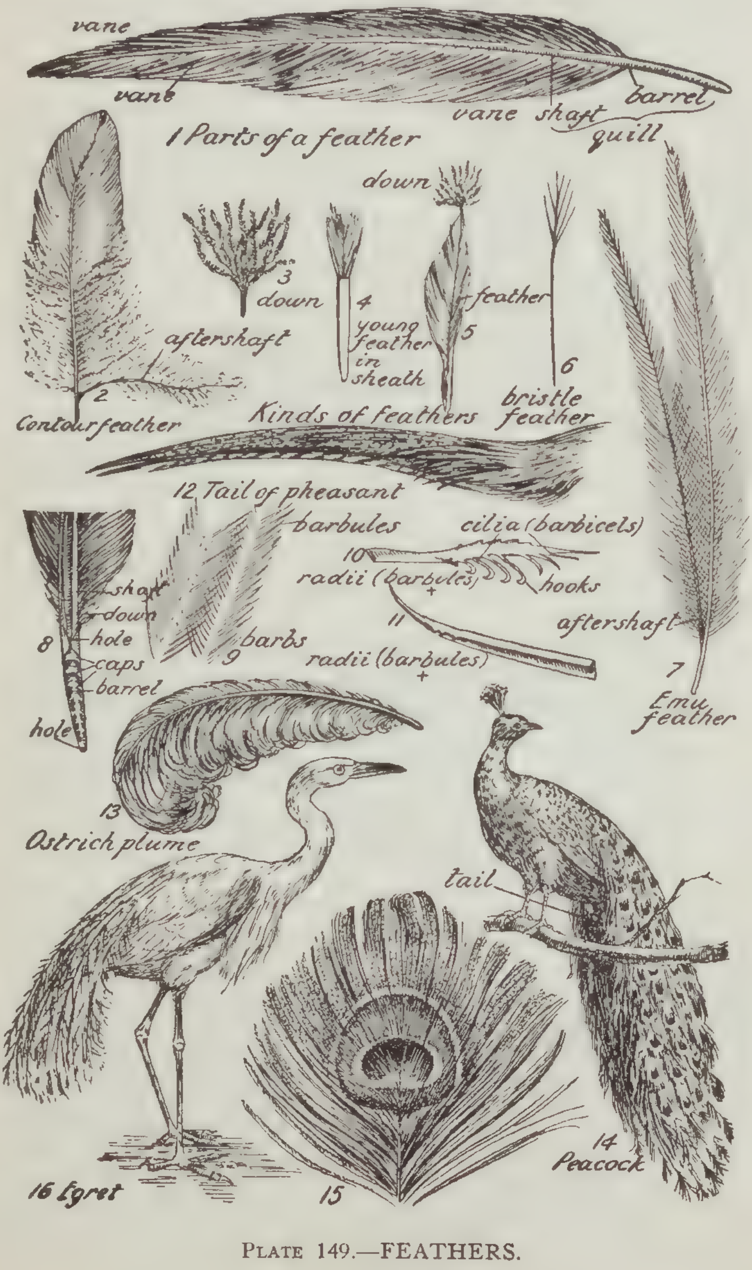


PLATE 149.—FEATHERS.

Feathers (149: 1) have a main central axis, the shaft; the inner transparent part, in which are horny "caps," is called the barrel. The barbs (main branches) have barbules (radii), which bear barbicels (hooks and cilia). A small hole where the blood-vessel emerged starts the opaque pithy axis. Here the after-shaft (149: 2), when present, joins the main feather. In emus (149: 7), the after-shaft almost equals the main feather. When present, it is usually on contour feathers (149: 2), and not on wing or tail quills. Contour feathers cover the body, giving it a smooth, even outline, and offering little resistance to the air.

Contour feathers, where overlapped by others, are not hooked (149: 2) together; they are down-like and warm without loss of material and without unnecessary workmanship. Ornamental feathers, such as those of egret (149: 16) and birds of paradise have no hooks. Bristle feathers (149: 6) or hair-like feathers (filoplumes) have a few barbs near the tip. They are common amongst the contour feathers; eyelashes are feather shafts.

Downs, having no hooks, are fluffy. They often arise from the one point on the central axis. In the cockatoos and some other unrelated birds, the down breaks into powder, "powder-down," resembling the fuller's earth that is used as a powder for babies. Stroke a cockatoo and see powder on the fingers, which become smooth.

Nesting down is absent in many birds, especially "nest-livers" (*Nidicolae*), the young staying in the nest for some time. The down is present in birds that leave the nest at once (*Nidifugae*); it is thick in young water-birds.

As ostriches are domestic birds, the more ostrich plumes (149: 13) worn the better, and the more birds there will be. The same remark applies to pheasants (149: 12), the long bright tail feathers of which are often worn by ladies. The wearing of egret plumes (149: 16), and bird of paradise, rhea, and albatross (147: 2) feathers means the death of the rightful wearer to satisfy the unnecessary whim of an unlawful wearer.

The peacock (149: 14, 15) has beautiful feathers on the lower back. The shorter tail helps to support and spread the beautiful tail coverts ornamented with "eyes."

The color of birds is due to pigment or surface structure breaking up the light, or a combination of pigment and structure. White is due to air in the cells. Almost any colored bird may produce an albino (white form) devoid of coloring matter. Melanism is the opposite, where excess of pigment gives a black appearance. Black, red, and yellow are the bird's pigments; brown is red and black mixed. A green or blue parrot's feather held against the light is seen to have no green or blue. These colors are due to surface effects on grey and yellow.

Sexual selection accounts for the bright coloring of many males, the females choosing the most attractive. Most females (*e.g.*, robins), sitting on the nest, are protectively colored. If nesting in a deep hollow, female parrots, *e.g.*, rosella, may be as bright as males. If males are brighter than females, they seldom share the duties of incubation, at least by day; they would be seen on the nest. Usually, where males differ in color from females, young males resemble the mother and acquire the brighter color later, the satin bower-bird (142: XXI.e) when about seven years old. The blue wren-warbler, an Australian beauty, is under observation. Does he lose his "nuptial dress"? Possibly so until four year old; possibly not after four year old.

Crimson rosella (frontispiece) adults are similar, crimson blue and black; the young of both sexes are green. Recently, however, it was discovered simultaneously in Great Britain and Victoria that some young crimson parrots omit the green phase and resemble the parents from birth.

I.—BIRDS' EGGS AND NESTS.

The yolk corresponding to the frog's egg has on top of it a small disc (150: 1, 2); the "baby chick" (*embryo*). The "baby chick" remains uppermost (150: 1). To enable the yolk to turn, it is supported and balanced, and one side is weighted. The white consists of two parts—a denser part outside the yolk membrane is continued at each end as the "balancers," supporting and balancing the real egg (yolk and embryo), and a thinner part in which the rest floats. The weighting of the yolk is interesting. Make a cross at the highest point of an undisturbed egg; boil it for ten minutes. Holding the egg with the cross upper-

most, remove the shells and white. Cut through the yolk from the "baby chick" with a sharp *wet* knife. The "baby chick" rests on lighter-colored "white yolk" (150: 1); next is yellow yolk; then white yolk (not the "white" of the egg); yellow yolk, and so on. The heavier yellow yolk is more abundant below.

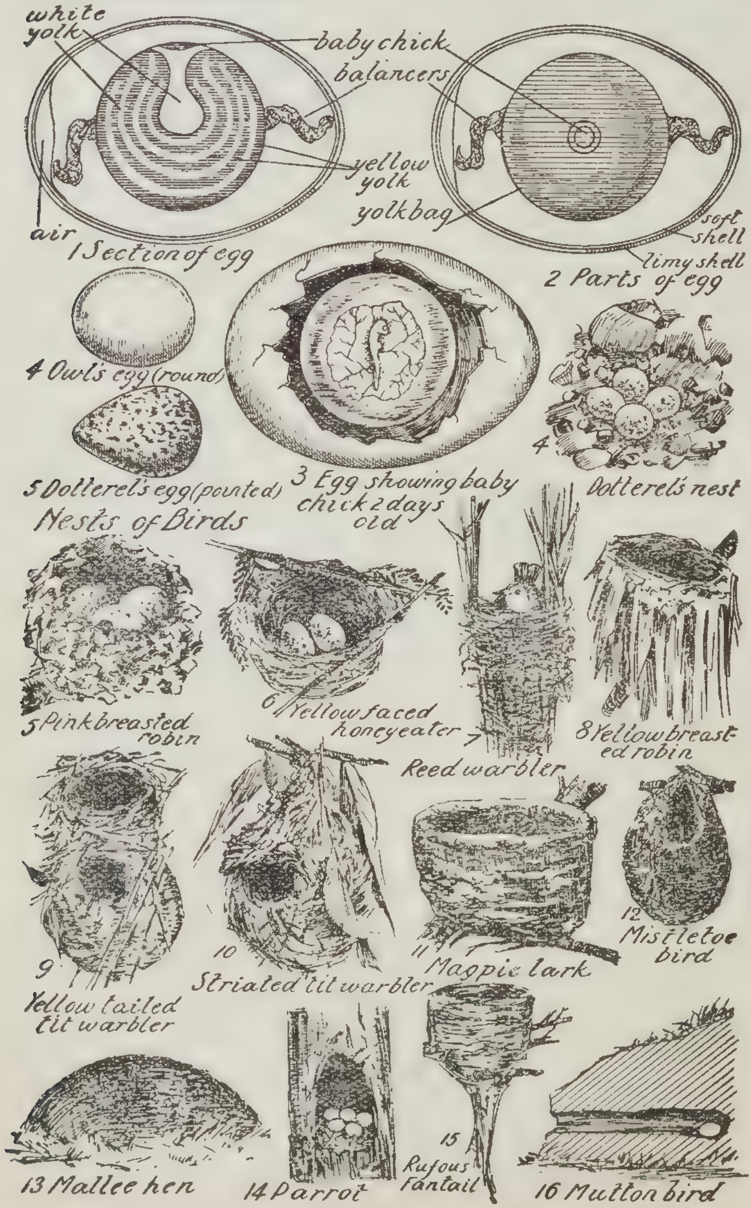


PLATE 150.—NESTS AND EGGS.

Outside the white is the double soft shell enclosing, at one end, the air that the chicken breathes before emerging. The limy shell over all is porous; oxygen passes in and carbon dioxide passes out. The yolk is food; the white is a protection and also food for the developing chick.

Hold an egg lengthwise between finger and thumb; you cannot break it. Eggs (sea-birds' and plovers') laid on cliffs or bare earth are pointed (150: 5). Even in a strong wind they do not roll far. Further, with the pointed ends inwards, they are more easily covered by the mother. Birds (owls) laying in hollow trees or in the ground (bee-eaters) lay, generally, rounded eggs (150: 4, 14). Eggs laid in dark places are usually white, reflecting what light there is; they are seen by the mother. Most eggs being protectively colored are hidden from enemies. Ground-laying birds lay mostly in surroundings matching the eggs. Everything is kept perfect. If the shell is too thin, it breaks during incubation; if too thick, the chick cannot emerge; if the food is insufficient, the chick dies; if the beak is too soft, it cannot break the shell. The chick has a special process ("egg-tooth") for breaking the shell. Once there is a break, it easily bursts the shell open. The "egg-tooth" soon drops off. Nature constantly selects the best to carry on the race. An egg is full of wonder, and is altogether perfect.

Dotterels and sandpipers lay pointed eggs extremely difficult to see (150: 4) amongst shingle and sand; there is really no nest. The cup-like nests of the pink-breasted (150: 5) and yellow-breasted robins (150: 8) are hidden and beautified by lichens in the first case, and suspended pieces of bark in the second; thus they escape notice. Some birds (orioles and yellow-faced honey-eaters) have "suspended nests" (150: 6). The reed-warbler (150: 7) makes a deep nest in easily-swayed reeds, and no egg rolls out. Striated Tit-warblers (150: 10) have a domed nest with a neat veranda. The mistletoe-bird, Australian flower-pecker (150: 12), makes a beautiful felted pocket-like nest.

The remarkable two-storied nest (150: 9) of the common yellow-tailed tit-warbler is a puzzle. Is the top nest for the male to rest in or to delude cuckoos? The white-shafted fantail's nest (150: 15, 187: 18) has a long tail

that possibly drains water from it or possibly carries the eye from the nest, which remains unobserved. The three Australian "mud-builders"—magpie lark (150: 11), white-winged chough, and apostle bird — are anomalous birds, whose classification presents difficulties as yet unsolved.

Parrots usually lay deep in hollows (150: 14). Being hidden, the female rosella is not dull in color. Red-backed parrots, laying in shallow hollows, possibly exposed to enemies have dull-colored females. Mutton-birds (141: VIII.) nest in burrows (150:16), often six feet deep. The mallee-hen lays in a mound (150: 13) those enormous eggs which contain much food. The young leave the mound fully feathered, able to run at once and to fly the same day.

CHAPTER XXV.

MAMMALS.

A.—INTRODUCTORY.

Mammals, animals having hair and suckling the young, are often called "quadrupeds," though many reptiles and some amphibians walk on four feet, while some mammals (kangaroo, jerboa, and man) are bipedal, and others (whales and dugongs) have front limbs only. All mammals during some stage of existence bear hair; and all, when young, live on the mother's milk.

All are warm-blooded, though the primitive egg-laying mammals, platypus (154: 1) and the spiny ant-eater (154: 2), vary somewhat in temperature. The lungs not communicating with air-sacs as in birds, there is a less complete aeration of the blood, and a consequently lower body-temperature than that of birds. At the top of the windpipe is the voice-box (larynx) (88: 9).

Professor J. A. Thomson says: "It is certain at least that the carefulness and sacrifice of the mothers have been one factor in the survival and success of mammals, and we may find in the term mammalia (*mamma,* a breast), which Linnæus first applied to the class, a hint of the idea that, in the evolution of this class, the mothers led the

way." Much sacrifice and work for the good of the race, rather than for the individual, were needed for progress

Being warm-blooded (constant-temperature) animals, mammals are more widely spread over the earth than cold-blooded reptiles, but, having less locomotory powers than birds, are not so widely spread as the latter.

Mammals, except flying bats, are totally absent from New Zealand and many oceanic islands.

Hairs are characteristic mammalian structures. "A bird is a feathered animal" is a complete definition, so is "A mammal is a haired animal," though adult whales and dolphins are hairless.

Mammals are remarkably uniform in color; to match the surroundings seems to be almost the sole purpose. Dr. Alfred Russell Wallace, the great naturalist and scientist, considered that "warning coloration" is exemplified by the white patch on the hind part of a deer and the white tail of a rabbit (153: 15).

One, scenting or sighting danger, quickly makes off; mates, seeing the white danger signal, follow. "Advertising coloration" is shown by the skunk. A dog does not attack a skunk the second time. He *recognises* the "advertising color" and avoids a second unpleasant experience of an objectionable persistent "stench." The tiger shows "concealment coloration;" it hides from its prey.

Possibly the general dulness of coloration is associated with rather poor sight. Mammals seem to depend more on smell and hearing. The ears are often large and conspicuous; the nose is also conspicuous.

Generally in mammals a neck joins the head to the body. The neck region of the backbone contains, with very few exceptions, whether in the long-necked giraffe or the practically neckless whale, seven joints.

The brain is highly developed, and constantly increases in bulk in an enlarged skull-cavity. The brain part of the head develops at the expense of the face portion, which shortens from that of a horse to that of a man. To increase the surface further, the brain of higher mammals is convoluted, "wrinkled with thought."

Teeth and limbs, the organs most affected by the diverse conditions under which mammals live, have been minutely

studied, and are most considered in the scheme of classification. The claim of a scientist, "Show me a tooth and a footprint, and I will reconstruct the animal," is no boast.

B.—TEETH.

Teeth are the hardest tissues in our body. Osborn says, "Though they are not improved as most tissues are by use, for they wear away, yet they are the most progressive of the tissues of the animal body. The more highly developed an animal is, the more specialized are its teeth."

Teeth procure food, seize and kill prey; gather and bite off vegetable food; fell trees; tear some food materials; cut, pound, or grind others; and serve as weapons of offence in some males (camels and some deer).

Consider first our own teeth (151 : 1). There are three kinds. The front teeth are "incisors:" they seize, cut, and

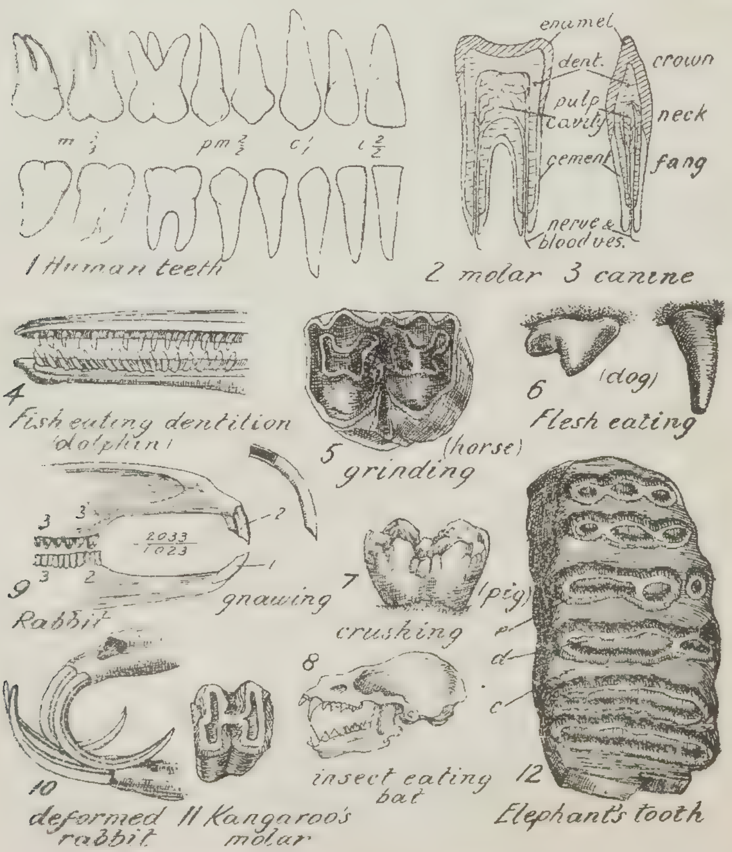


PLATE 151.—TEETH OF MAMMALS

hold. The conical-pointed tooth (6), better developed in dogs, is the "dog tooth" or "canine." The back grinding and pounding teeth are of two sets; the front two, the pre-molars, like the incisors and canines, come twice; there is a milk tooth before each. The following three, the molars, have no milk predecessors. A child has five teeth on each side of each jaw—two incisors, one canine, and two pre-molars; twenty teeth. An adult has three molars additional on each side: total, thirty-two.

Teeth, though hard, wear out, and, worse still, decay. A tooth, having a complex structure (151: 2, 3) consists largely of toothbone—dentine, which resembles bone. To protect it there is hard enamel on the "crown." To nourish the tooth, there is a blood supply and a nerve in the "pulp cavity." If there is a "hollow," one realizes how sensitive the nerve is. As only enough blood enters to nourish the tooth, it does not grow. A developing tooth with open root has a good supply of blood.

A fourth substance, "cement," is more important to grass-eating animals. Our back teeth have cusps or elevations (7), which pound or crush food. Generally, our teeth form a close row; in horses (156: 1) a space separates front and back teeth.

Man's teeth (151: 1) are adapted to an *omnivorous* diet. Barracoutas and dolphins (151: 4), living on slippery fish which they do not chew, have uniform sharp-pointed teeth —*fish-eating* (*piscivorous*) teeth. Bats and moles have teeth with sharp points or cones—"*insectivorous*" teeth (151: 8); these treat small insects effectively. Dogs and other flesh-eaters have back teeth (158: 9, 10) closing like scissors and cutting flesh into pieces, swallowed without chewing, and pointed canines to kill their prey; they have "*carnivorous*" teeth. A horse (151: 5; 156: 4) and cow (156: 5) have ridged *herbivorous* teeth, which grind vegetable food.

As teeth are so important, scientists have a simple way of indicating them. Our teeth consist of eight on each side of each jaw. This is shown briefly thus:—

$$i\ \tfrac{2}{2},\ c\ \tfrac{1}{1}\ p.m.\ \tfrac{2}{2},\ m\ \tfrac{3}{3},\ \text{or better } \tfrac{2123}{2123}.$$

reading thus—incisors, 2 above and 2 below; canines, 1 above and 1 below; pre-molars, 2 above and 2 below;

molars, 3 above and 3 below. The typical full set, as in the pig (157:7), is 44, ${}^{3143}/_{3143}$. The dog (158:9) has 42, ${}^{3142}/_{3143}$. The horse has ${}^{3133}/_{3133}$. The horse's teeth (151:5; 156:4) have ridges and folds of dentine and enamel coated with cement. The harder enamel projects as ridges, forming a characteristic pattern. These "crescentic-ridged" teeth form an efficient masticating organ. Herbivorous kangaroos (151:11) have a characteristic H on the molars. The pig (151:7; 157:5b) has cusped molars—pounding teeth—somewhat like ours. The long, curved canines of a boar are formidable weapons. Rabbits, ${}^{2033}/_{1023}$, (151:9; 159:2), and other "rodents," have front teeth that grow continually from "persistent pulps," and have enamel on the front edge. The dentine wears away, giving a chisel-edge of enamel useful in gnawing. Sometimes the lower teeth (151:10) do not meet the upper; they then grow in a curve and may pierce the brain, killing the animal. The teeth, perfect-ridged mill-stones, of the elephant (151:12) are treated later.

C.—ARMS AND LEGS.

Arms and legs (152), being much modified to meet varied environments, are interesting.

Vertebrates never have more than two paired limbs. Whales, eels, and dugongs have no hind limbs; some snakes and lizards have no front limbs and much-reduced hind limbs, while lampreys and most snakes have no paired limbs. The swimming paddle of whale and seal, the bird's feathered wing, the bat's membranous wing (159:6, 9), the burrowing organ of mole and spiny ant-eater (154:2), the jumping leg of frog and kangaroo (152:C1, C5), the running leg of horse (152:A2, B1; 156:6, 7), and dog (158; 152: A4), the supporting leg of man (152: B2), and bird (152:B5), and the grasping hand of monkey and man (152:A1), are modifications of similar structures, fitting different animals for different modes of life.

Consider first our own limbs. The arm (152:A1) has three main parts; upper-arm, forearm, and hand, including wrist, palm of hand, and fingers. The leg (152:B2) similarly has thigh, shin and foot, including ankle, sole of foot, and toes.

The upper-arm has one bone with a rounded top; the fore-arm has two bones which turn the palm up or down. Kangaroos also turn the hand over. The fore-arm bends on the upper arm by a "hinge joint." The "ball and socket" shoulder joint allows circular movement. Hand is joined

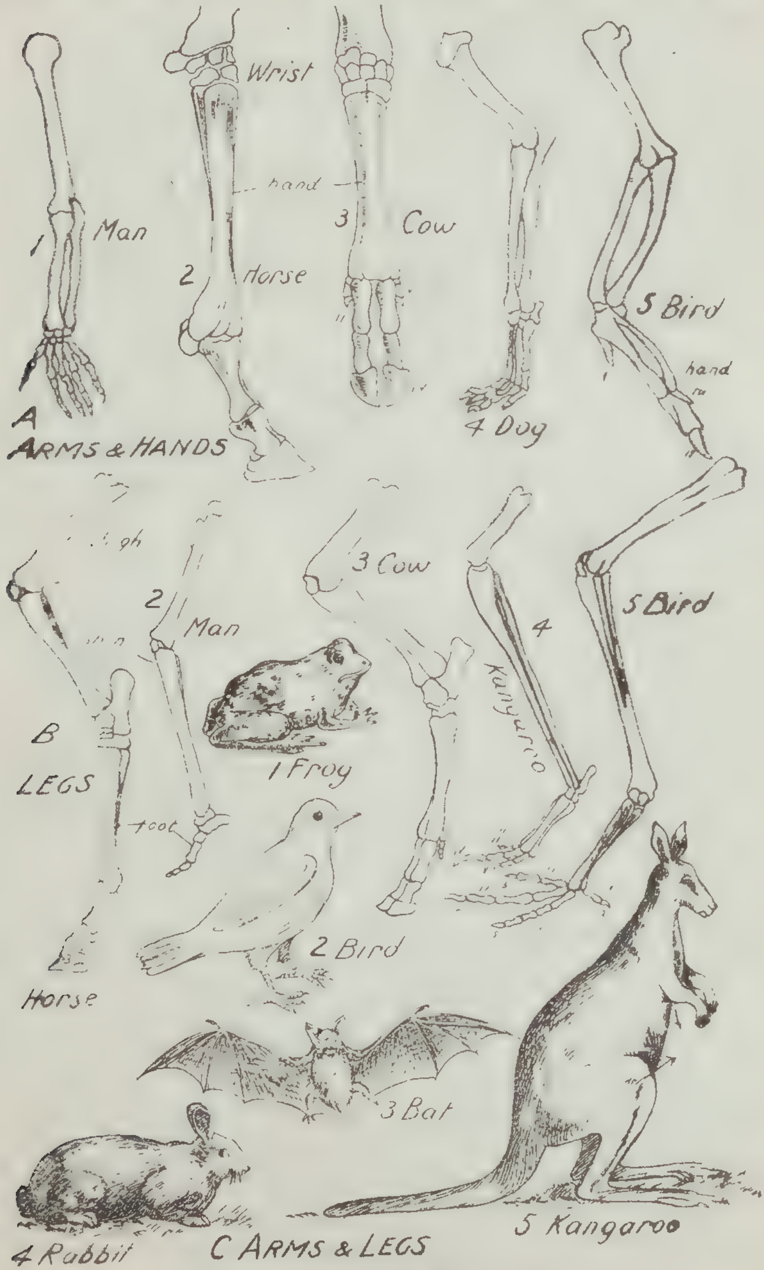


PLATE 152.—ARMS AND LEGS.

to forearm by a hinge joint between the forearm and wrist-bones. There is little movement between the seven small wrist bones. Each of the five hand-bones bears a finger. Four fingers have three joints; the first, the "thumb" (*pollex*) has two joints; the second, is the "index" or "pointing" finger; the third, the "middle" finger; the fourth, the "ring" finger, and the fifth, the "little" finger.

Legs (152: B) resemble arms (152: A). The thigh bone with a rounded ball-top is attached to the two shin bones by a hinge joint, protected by the "knee-cap," which is absent only in some marsupials. The ankle joins ankle-bones to shin with a hinge-joint. The long heel-bone receives the tendon of the calf-muscle. The ankle has several small bones. Usually, ankles are less modified than wrists, and hind limbs, having less variety of functions, than front limbs. The five foot-bones bear the five toes. The inner toe has two joints; the others, three. The toes, except the first (hallux) have the same names as the fingers, index, middle, ring, and little toes. The legs supporting and moving the body are well adapted to these functions.

Our hand is a beautifully-modified grasping organ. The "opposable thumb" can be brought opposite each finger; the nails effectively protect the sensitive finger ends, delicate organs of touch. The toes also bear nails.

The *HORSE* is a perfectly-adapted animal. The cheek teeth (151: 5; 156: 4) are perfect mill-stones, grinding quickly much food required by an active animal. The limbs (156: 6, 7; 152: A2, B1) are greatly modified; upper-arm, fore-arm and wrist are somewhat as usual; the profoundly-altered hand is narrow and lengthened, serving well for speed. The one large hand-bone bears one finger. The horse runs on the tip of the middle finger. The hoof, corresponding to our nail, effectively protects this; the three bones of "foot" and fetlock are those of the middle finger; the so-called shin, the "cannon bone," is the middle hand-bone, with reduced second and fourth hand-bones, "splint bones;" the so-called knee is the wrist. Every elbow bends backwards. The horse's elbow (156: 6) is 156: 7), the bones of hind "foot" and fetlock are the three

bones of the middle toe. The hind "cannon bone" is the middle foot-bone, with reduced second and fouth foot-bones; the hock is the heel Knees bend forward. The horse's knee is close to the flank.

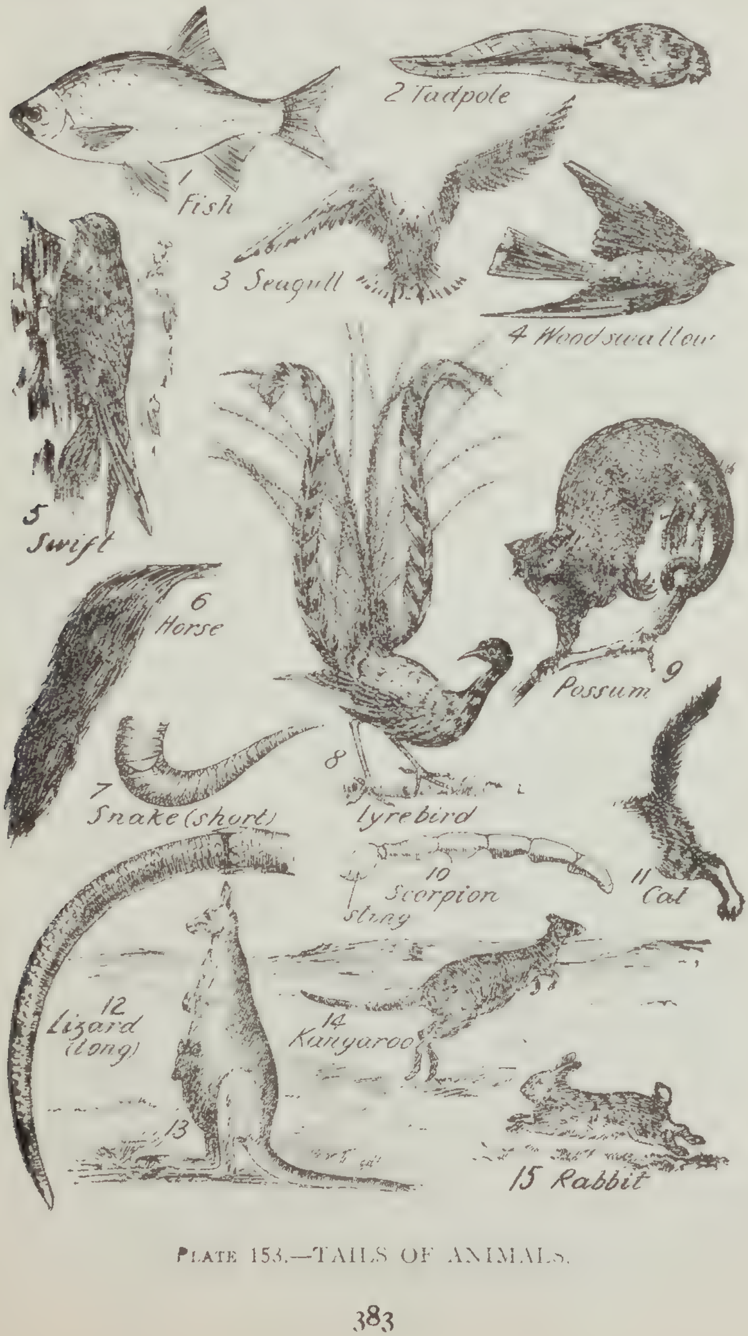


PLATE 153.—TAILS OF ANIMALS.

In cows (156:8) and sheep (157:4) the weight of the animal comes between the third and fourth toes, each bearing a hoof flattened on the inner side, suggesting a large split hoof; hence "cloven-hoofed." The second and fifth toes are reduced (152: B3), and the first toe has disappeared. When one toe is lost, usually it is the first. If a second toe is lost, it is the fifth. Horses are "odd-toed, hoofed animals;" cows are "even-toed hoofed animals."

Horses and sheep walking on the tips of fingers and toes, and dogs, cats and birds walking on the length of fingers and toes are "finger-walkers," digitigrade. Bears and men walking on hand or foot are "foot-walkers," plantigrade.

The bipedal kangaroo (152: 5; 153: 14) has five-fingered hands which rotate. The jumping hind limb (152: B4, C5) is large and strong, the much lengthened foot has no first toe (B4); the small second and third toes are united; the fourth toe is large, strong, and bayonet-like; and the fifth fairly strong. The bat's front limb (152: C3; 159: 6, 9) is a wing; the short thumb is hooked; the four long fingers bear the web, forming the only true flying organ found, amongst mammals. Bats walk little. The five strongly-clawed toes (159: 8, 9) grasp a branch or ledge as the bat hangs head down.

The bird's limbs (143: 152) are treated elsewhere.

D.—TAILS OF ANIMALS.

Tails (153), though less important than arms and legs, catch the eye and provoke investigation. In mammals, the backbone is continued into the long, jointed tail.

In whales and seals, reminiscent of fish and tadpole, the tail is an organ of propulsion. While the fish's tail (153: 1) is vertical, the whale's tail is horizontal, and proves a dangerous weapon of offence against a boat's crew.

In possums (153: 9) and some monkeys the tail is prehensile, and is a climbing organ. One rat-kangaroo (154: 5) carries grass with its tail. Horses (153: 6) and cows use it to drive away flies. The possible danger signal of the rabbit's tail (153: 15) has already been noted.

The cat's tail, too, is used somewhat as a danger or bluff signal; when faced by a dog it bristles up; the hairs stand on end, and the cat tries to look twice its normal size.

The kangaroo (153: 13, 14) uses the large tail as a balancing pole when racing, a prop when sitting, and a fifth leg when feeding and progressing slowly.

Lizards are often confounded with snakes, but usually they have a long tail (140: 1; 153: 12), while snakes (140: 6; 153: 7) have a short tail.

Birds use the tail for many purposes—as a brake (sea-gull, 153: 3); as a prop (spine-tailed swift (153: 5), or sparrow on a wall); as a warning signal in the white-tipped tail of the wood-swallow (153: 4) and others, the two plain center feathers hiding the white when at rest; as an ornament in lyre-bird (153: 8), and as a rudder.

The tail is absent in the native bear (Koala), wombat, guinea pig, and apes.

Some invertebrate animals have a tail; the scorpion (153: 10) has the poison sting in the long-jointed tail.

E.—EGG-LAYING MAMMALS.

Platypus (154: 1) and spiny ant-eater (154: 2) — the egg-laying mammals—are of such great interest that they take an order to themselves. Beddard considered them of greater scientific importance than the whole of the marsupials. They retain many ancient structures relating them to reptiles. The remarkable *PLATYPUS* or duckbill mole (18″ body + 6″ tail) was once considered a fraud. It is named from the bird-like bill, *Ornithorhynchus paradoxus*. It has a duck-like bill, webbed hands with webs reaching past the fingers, a spur with a poison gland on the hind leg, and beautiful fur. The limy teeth of the young are replaced by horny plates, possibly more serviceable in crushing shell-fish. The platypus is not often seen, though sometimes caught accidently by fish-traps and fishing-lines. Its burrow has the entrance below water. A higher price is now offered for the egg than for almost any bird's egg. Rarely a platypus is seen in the Yarra above Dight's Falls. It is found in Tasmania and Eastern Australia. It lays eggs, and the young live on milk in a temporary pouch.

The *SPINY ANT-EATER, Echidna* (154: 2), wrongly called a porcupine, is a burrower. A concrete floor is said to be the only thing to withstand the powerful claws. It tucks in head and feet, and presents spines to an enemy.

The head is prolonged into a toothless beak, the long, protrusible, sticky tongue gathers ants. The egg is carried in the temporary pouch, where, later, the young feed on milk. It has a wide range across Australia.

F.—MARSUPIALS.

Marsupials—pouch-bearing animals—are best developed in Australia and adjacent islands; they are now confined to America and Australia. Most females have a pouch, in which the young are carried and fed for a lengthy period. Some marsupials, however, have no pouch, and some mammals with a pouch are not "marsupials."

Teeth and limbs are used in classifying Marsupials. The more general classification is based on the lower front teeth. Kangaroos have *two* lower front teeth. Marsupials so provided are *Diprotodontia* (*di* two, *protos,* first, *odous oudontos,* a tooth). Marsupials with many lower front teeth are *Polyprotodontia* (*poly,* many). Diprotodonts have two families, containing seven subfamilies, namely, (1) the kangaroos and wallabies, (2) rat-kangaroos, (3) the musk-rat of North Queensland, (4) possums and flying squirrels, (5) koala, the native bear, (6) wombats, (7) the small mouse-like flower-visiting Tarsipes.

The carnivorous Polyprotodonts have four families — the "Native Cats," including the Tasmanian Devil (154: 13) and the Tasmanian Tiger or Wolf (154: 15); the American Opossums, Bandicoots, and the marsupial mole (155: 4). Another classification uses the bound second and third hind toes, the "syndactylous foot" This unites bandicoots and the Marsupial Mole, with Diprotodonts as *Syndactyla,* and leaves Polyprotodonts minus bandicoots and the marsupial mole as *Diadactyla,* with second and third toes free.

Kangaroos and wallabies are distinguished by size. Lucas and Le Souef call those less than four feet high wallabies, and those over four feet high kangaroos. They list fifteen kinds of wallabies and five of living kangaroos. The Great Red (65″ + 42″), the Wallaroo (60″ + 36″), and the Common or Great Grey Kangaroo (60″ + 37″) are the three common *KANGAROOS.* All have a naked nose (154: 3; 152: 5; 153: 13, 14); well developed ears, two lower front teeth, small five-clawed front feet, and long

strong hind feet (152: B4). The inner toe is absent; the small second and third toes are united in one sheath; the fourth toe and claw are long and strong, and the fifth toe is also strong. Kangaroos are jumpers, the tail acting as a balancing pole (153: 14). When standing erect (153: 13) the tail is a prop. When feeding, the animal progresses on four feet and tail. An "old man" kangaroo is a dangerous opponent; it hugs with the front feet, and disembowels with the formidable bayonet-like fourth toe.

When born, the immature young is about an inch long, with front limbs longer than the hind. The minute, blind, helpless animal is placed on the teat by the mother, who with a special muscle, forces milk into it. The teat swells and the young cannot slip off. If pulled off, the mouth is torn. Bushmen then declare the young are "born on the teat." They are fed in the pouch for months.

The Pademelon (25″ + 16″) is a "very light and graceful little wallaby (body 25in. long, and tail 16in.).

Tree kangaroos, with nearly equal limbs and long tail, are found in North Queensland. Rock Wallabies, with short fourth toes, live amongst rocks.

The Rat-kangaroos (14″ + 12″) have a rat-like head. Some have a prehensile hairy tail, with which grass is carried to the nest (154: 5). The diagram is too large.

Australian vegetarian possums (18″ + 11″) (154: 6), with second and third hind toes united, two lower front teeth and a hairy tail, resemble slightly, in external form, the carnivorous American Opossums, with many lower front teeth, second and third hind toes free, and a scaly tail. The Californian gold miners in the fifties applied American names to many unrelated Australian animals and plants. "Gum-tree," "iguana," and "opossum" are three such names.

The common possum (154·6), with its grey coat, black, bushy, prehensile tail, and prick ears, is found in wooded country. It has the inner toe of the hind foot (6) opposable, suggesting the foot of the tree-climbing monkey. This hind "thumb" has no claw or nail.

The nest-building ringtail possum (154: 7), with prehensile tail, is smaller (16″ + 14″). Two fingers on the front foot oppose the other three forming a seizing hand. It has a "thumb" on the hind foot.

Beautiful flying possums or squirrels (154: 8, 9) of three sizes—large, brown and white (17″ + 20″), also pale gray (10″ + 11″), and small, silver gray (7″ + 8″)—have a fold of skin connecting front and hind limbs. They volplane a considerable distance to the ground.

The feather-tailed pigmy flying-possum (3″ + 3″) is a dainty little pet (154: 9). It is often found by young observers. These flying-possums are remarkably tame.

The quaint *KOALA* (154: 11) or native bear (32″) has large round ears, black muzzle, and no tail. The young often rides on the mother's back.

The heavy-bodied, clumsy *WOMBAT* (44″), with strong digging claws (154: 12), out-rodents the rodents for all its teeth ($^{1014}/_{1014}$) grow from persistent pulps. The heavy

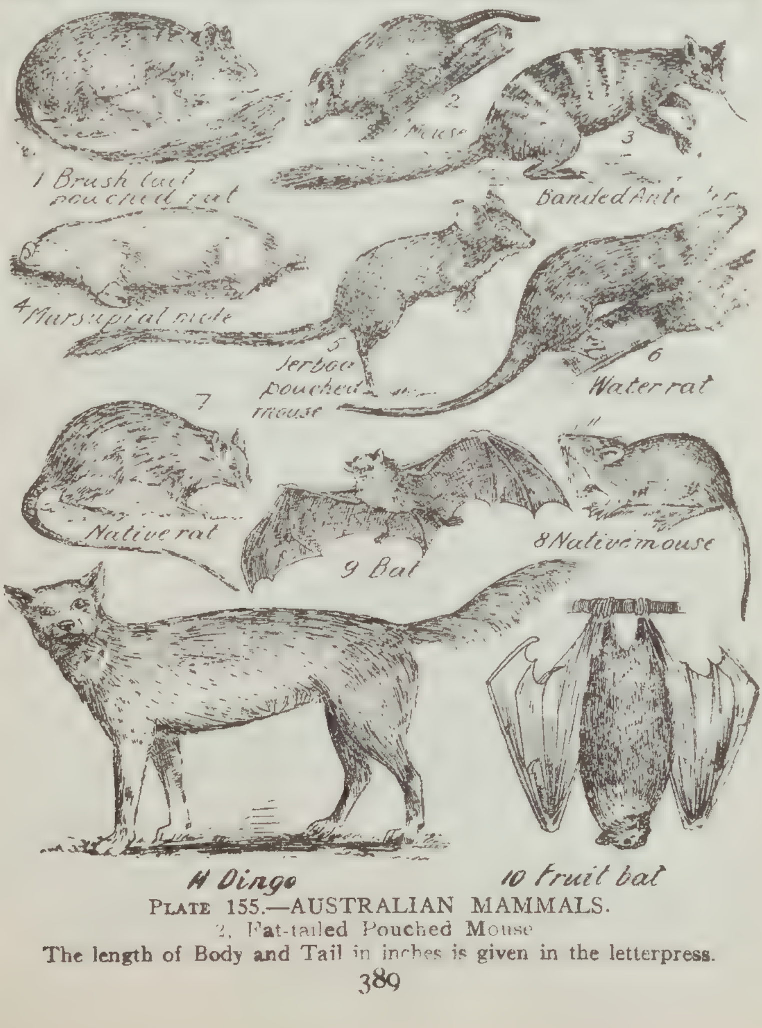


PLATE 155.—AUSTRALIAN MAMMALS.
2, Fat-tailed Pouched Mouse
The length of Body and Tail in inches is given in the letterpress.

Gymnobelideus ($5\frac{1}{2}'' + 6\frac{1}{2}''$) is one of the rarest of mammals (154 : 10). Five specimens only are known; they came from the Bass River Valley, East of Western Port. Probably this interesting little mammal is extinct.

Plate 154.—AUSTRALIAN MAMMALS.
The length of Body and Tail in inches is given in the letterpress

solid lower jaw is sometimes found lying about Wombats break through wire-netting fences and cause annoyance to settlers close to river cliffs. They sleep in a burrow by day. The tail is rudimentary. The flesh is said to taste like pork.

Extinct marsupials of great size have left their remains in swamps, where the animals were bogged in the mud. Diprotodon was as big as a rhinoceros; giant kangaroos were 12 feet high.

The carnivorous native cats and their allies have many lower front teeth. The Tasmanian devil (28″ + 12″) (154: 13) once lived on the mainland. The dingo—a true dog—probably could not equal the devil in a fight; but, having a larger brain, beat it in the struggle for existence. Skulls of the devil are occasionally found on the mainland. A devil was killed a few years ago near Heathcote; it probably escaped from a circus.

The Tasmanian wolf or tiger (44″ + 21″) (154: 15), as large as a sheep dog, occasionally causes loss to sheep-owners. Like the devil, it is now confined to Tasmania.

The white-spotted and black-spotted native cats (18″ + 12″) (Dasyures) (154: 14) were considered different species until found in the same litter. These once common animals have mysteriously decreased in numbers during the past twenty years; they once killed poultry.

BANDICOOTS (14″ + 5½″) (154: 16) have many lower front teeth (4 or $^{5134}/_{3134}$). They connect marsupials with higher mammals and also, on account of the syndactylous foot, connect the two-lower-front-teeth forms with the many-lower-front-teeth forms. They are of various kinds. Long-eared Rabbit Bandicoots (18″ + 12″) (154: 17) resemble rabbits; others are rat-like. The moist nose, giving a cold, miserable appearance, is the origin of the Australian saying, "as miserable as a bandicoot." The rare pig-footed bandicoot has pig-like feet.

The greater brush-tailed pouched mouse (10″ + 9″) (155: 1) is a graceful animal, too large to be called a mouse. It may live above the ceiling of a house, and is said to kill fowls, though it is mainly insectivorous. Several kinds of pouched rats and mice are known. The fat-tailed pouched mouse (5″ + 3″) (2) has a fat tail.

The West Australian banded ant-eater (10″ + 7″) (155: 3) has a bushy tail, but no pouch. It has a long protrusible tongue and feeds on ants. "It may be an unmodified survivor since Mesozoic times."

The remarkable, rare marsupial mole (*Notoryctes*) (6″ + 1″) (155: 4), with rudimentary eyes beneath the skin and no external ears, flattened shovel-like claws, hard burrowing nose, naked tail acting as a fulcrum, and beautiful fur, is found only in the dry interior of Australia. In sandy country it is a most rapid burrower.

American Opossums have 50 teeth ($^{5134}/_{4134}$); the pouch is generally absent. There are 23 species, most of which are found in South America. Some eat fish; some, crabs.

The jerboa pouched mouse (4″ + 5″) (155: 5), small and graceful, with large oval ears, has a tufted tail.

Except for true flying mammals, a field occupied by bats, the varied Australian marsupials developed to hold every field occupied by the many orders of higher mammals—ant-eaters, hoofed animals, carnivora, and insectivora. Though marsupials once lived in Europe, they were minute rat-like forms, not like Australian marsupials.

G.—HIGHER MAMMALS—EUTHERIA.

The higher mammals are divided into nine orders.

The first—*Edentata*—includes sloths, American anteaters, Armadillos and the Cape ant-eater. Teeth are absent or imperfect. Edentates are mainly South American.

The dugong of North Australia and the manatees of Africa and South America form the second order.

Whales and dolphins are fish-like, but have a horizontal expanded tail, the fore limbs are paddles, the hind limbs are absent. Dolphins are common in Port Phillip Bay, but no porpoise is found in Australian seas. The rorqual whale, 85 feet long, is the "most gigantic" of all vertebrate or other animals, in spite of much popular natural history. The nostrils of whales are directed backwards, and open in the top of the head. The warm breath shows as a vapor column, as our breath does on a frosty morning. The whale does not really spout, though it may blow against the water on returning to the surface.

Hoofed animals (Ungulates) are all toe walkers. Horses have one toe, while sheep, pigs, and cows have two functional toes on each foot. Usually fingers and toes are protected by hoofs. True hoofed animals are divided into

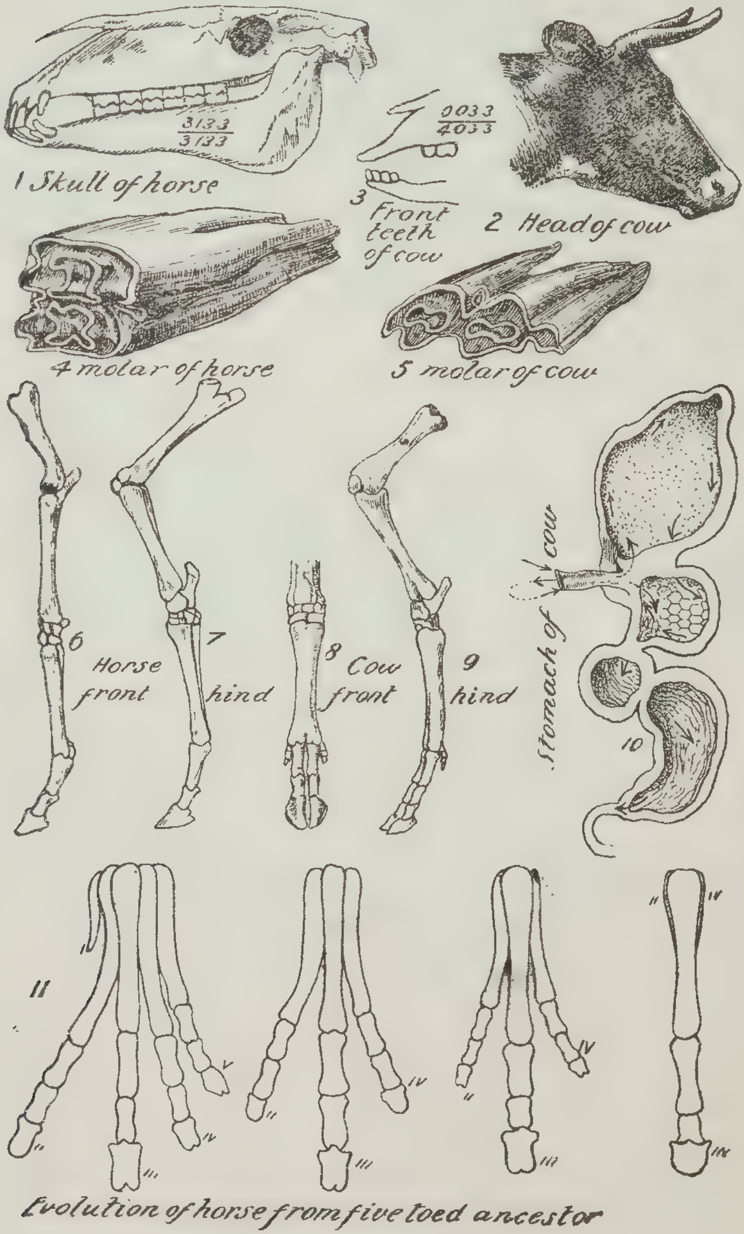


Plate 156.—HORSE AND COW.

even-toed (cows) and odd-toed forms (horses). Pig and camel, deer, giraffe, cattle and sheep (ruminants), are even-toed hoofed animals.

The lower front teeth biting against a callow gristle pad (156:3; 157:6) on the upper jaw tear vegetable food; this is passed down to the first stomach to be softened, and into the second, where it is made into convenient-sized balls. While resting, ruminants "chew the cud," bringing a ball back to the mouth, chewing it and passing it to the third to be filtered, and the fourth to be digested.

Cows and sheep have crescentic ridged teeth (156:5; 157:5a), the harder enamel forming ridges to grind food. A pig has cusped pounding teeth (151:7; 157:5b), resembling human molars; and long canines (157:7).

The cannon bone of front and hind shins of cows (156: 8, 9) represents the four hand-bones and four foot-bones respectively fused into one bone; the second and fifth toes are small. In sheep, the cannon bone (157:4) is the third and fourth bones fused, the second and fifth being small

PLATE 157.—SHEEP AND PIG.

and not bearing toes. A pig has the four hand-bones (157: 3) third and fourth are large, second and fifth small.

Deer (solid-horned ruminants) are absent from Australia and Africa. The male sheds the antlers each year, and each year the antlers gain an additional prong. Hollow-horned ruminants (sheep, goats, and antelopes) are abundant in Africa. They were absent from Australia and Central and South America.

The Hippopotamus "river horse" is an even-toed hoofed animal; the family is placed next to that of the pig.

Odd-toed animals are grouped into three families: the horse, tapir, and rhinoceros families.

Gradually, through long ages, the horse became a galloping machine, able from birth to run to escape enemies. By the bones of extinct animals, the horse is traced back to five-toed (156) ancestors, no larger than a fox. These travelled slowly over swampy country. As the earth became drier and grasses developed, higher speed became possible. Animals with reduced side toes had the advantage, escaped more easily from enemies, and obtained more food in times of stress. The advantage was with the stronger center toe (156: 6, 7), and the second and fourth toes were lost. The second and fourth hand-bones persist as small splint-bones. The usual dental formula is $^{3133}/_{3133}$ The first pre-molar, the "wolf tooth," is very small (156: 1), and is mostly absent. It is a disappearing tooth. Wisdom teeth, which come at the age of over 20 or not at all in some men, are also probably disappearing teeth.

Elephants form a sub-order of hoofed animals. They have stout pillars of legs to bear the massive body. The short neck bearing the heavy head is unusual; the length of the neck generally corresponds with that of the front legs, so that the grass-eater can reach the ground for food. The marvellous trunk more than compensates for the short neck. These animals were previously grouped as *Pachydermata* (*pachys,* thick; and *derma,* skin).

Cutting a molar is a serious business with elephants; they suffer much with tooth troubles. The large molar (151: 12) has enamel folded up and down over the much-folded dentine; cement fills between the ridges of enamel. As the tooth wears, perfect ridges are formed for grind-

ing food; and as one tooth wears out, another grows from behind. The tusk is a canine tooth, growing from a "persistent pulp."

The order Carnivora includes the large beasts of prey —lions (cats), wolves (dogs), bears, otters and seals.

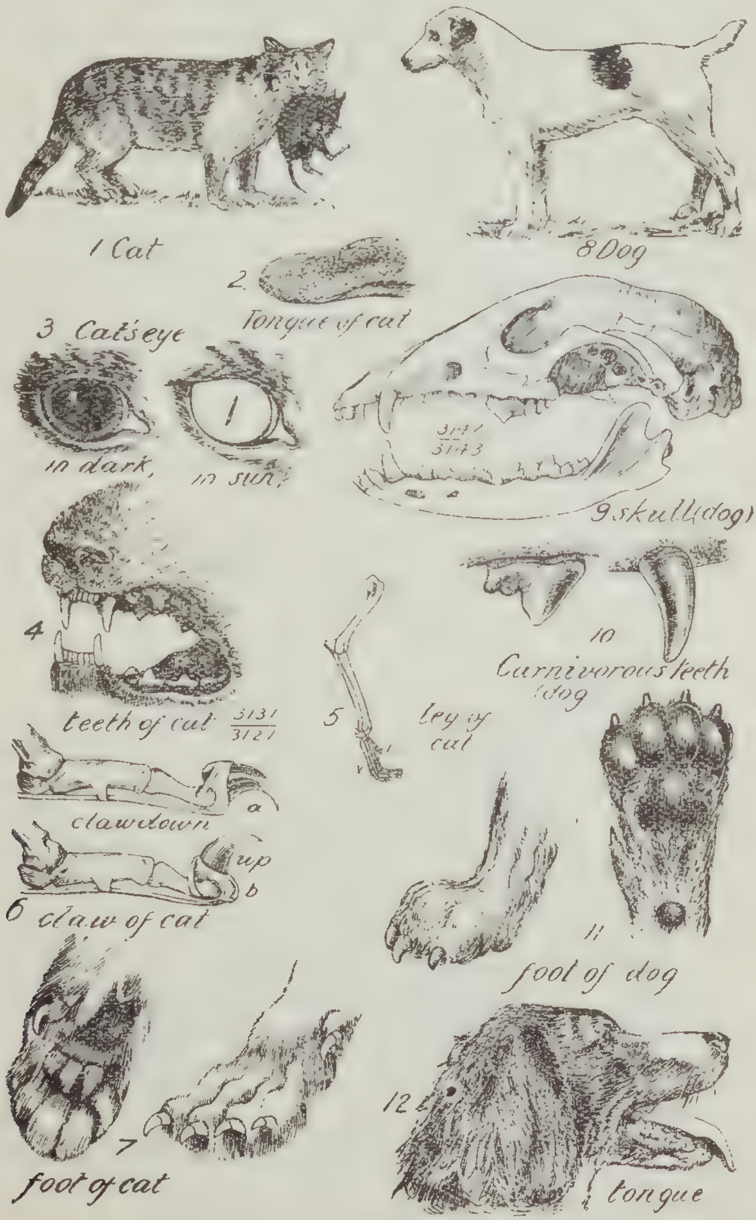


PLATE 158.—CAT AND DOG.

The toes and fingers are never less than four, and all bear claws, blunt in dogs and sharp in cats. The canine teeth are strong and sharp; some back teeth form a cutting organ, slicing the food swallowed without chewing.

Cats, dogs, and bears are the types of the three groups. Cat-like carnivores include cats, lions, leopards and jaguars. The dental formula for cats is ${}^{3131}/_{3121}$. The rasping tongue (158:2) may draw blood. Cats must be considered highly perfect for their mode of life. The short jaws, the one molar being small, with wide gape, long canines, and sharp-shearing cheek teeth, a rasping tongue, sensory whiskers to assist in finding the way in the dark, a wide open pupil to let in all light possible, reduced to a slit in the sun. The sharp claws are retracted, but can easily be pulled down when required. Pads on the feet reduce noise and jar.

Dog-like carnivores include dogs, wolves, jackals, and foxes (${}^{3142}/_{3143}$). They have the skull (158:9) larger than that of cats (158:4). There are five fingers (152:4), the first being reduced. The claws (158:11) are non-retractibie and blunt. The dingo, the only true carnivore native to Australia, is a puzzle. If it spread here naturally, why did not other forms come here with it? Some consider it reached Australia naturally. Many, however, think it was introduced into the north by man.

Bears are plantigrade—foot walkers. The teeth are—${}^{3142}/_{3143}$. They are absent from Africa and Australia, and have only one species in South America. Otters, badgers, stoats, ferrets, and weasels are bear-like carnivores.

Seals and walruses make up a separate order of little concern in nature study.

Rodents (gnawing quadrupeds)—the most numerous in kinds and possibly in individuals of all mammals—have caused much loss in Australia. Rabbits have cost millions, and still flourish: mice are doing much harm at present in the great stacks of wheat awaiting transport.

The beautiful, weasel-shaped water-rat (155:6) (11″ + 9″) may be seen here in lakes or river. It eats shell-fish as well as pond plants. Rats (6½″ + 4″) and mice were found all through the Eastern Hemisphere, except Madagascar. They have reached even remote islands before shipping was available: but now they travel freely by ship.

Rabbits and hares are long-eared, short-tailed, and with a small tooth behind each upper gnawing incisor. Rabbits and hares were cosmopolitan, except for Australasia and Madagascar. Rabbits have five fingers and four toes. The inside of the cheeks and the soles of the feet are hairy. Rabbits produce naked young in a nest or burrow. The solitary, defenceless hare sits in its "form" near a log or in grass or ferns. It sometimes watches a man walk within a few feet of it. The young leverets are born furred and with open eyes; they soon escape danger. The

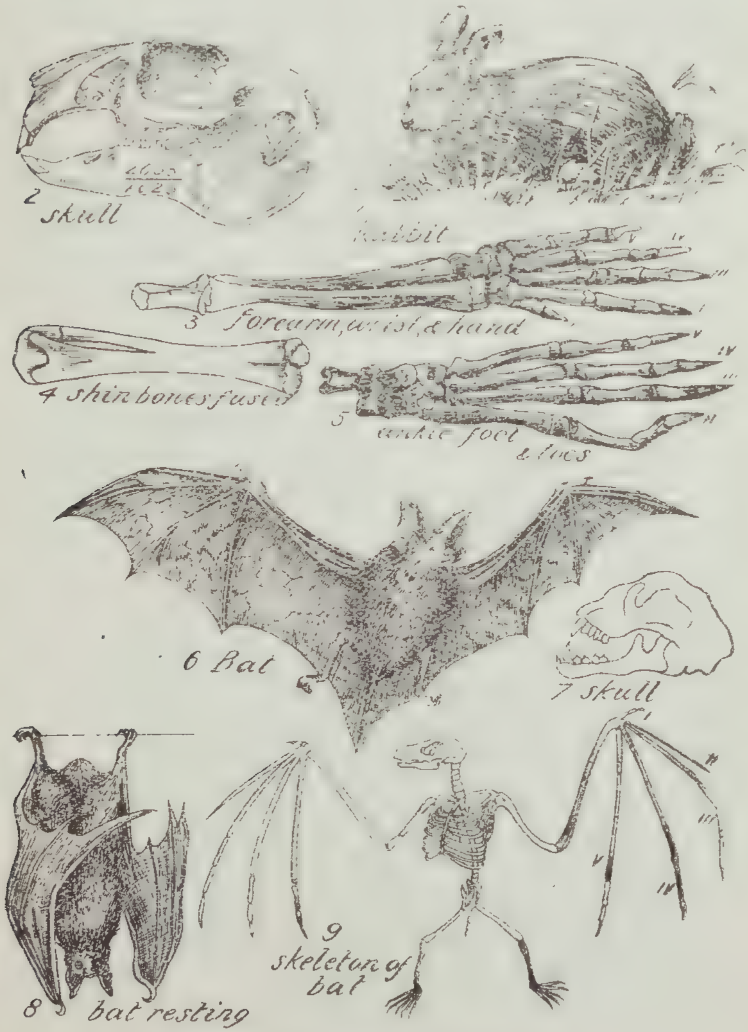


PLATE 159. RABBIT AND BAT

long black-tipped ears help to distinguish a hare from the shorter-eared rabbit. The hare also has longer hind legs.

True Insectivora, *e.g.*, hedgehog, mole, and shrew, small mammals with sharp-coned insectivorous teeth (151 : 8) are absent from Australia, their place being taken by modified marsupials, *e.g.*, the banded ant-eater, the marsupial mole, and bandicoots. Insectivorous opossums replace true Insectivora in South America

Bats (159: 6), highly specialised for flight, have reached all the big land-masses of the world, including New Zealand. The wing is the characteristic structure. The thumb is always clawed. In addition, the index finger is clawed in fruit bats (flying foxes) (159 : 8). The legs are weak, and the knee bends outwards, the one exception to the rule that knees bend forward. The five toes are clawed. The sense of touch is remarkably well developed. Bats, true mammals, suckle their young, and are clothed with hairs; they are divided into two sub-orders:—(1) Big bats, fruit bats, "flying foxes" (159 : 8); (2) small insectivorous bats (159 : 6).

The last order of mammals contains the highest of vertebrates—*PRIMATES*. Nearly all primates are adapted to a tree life. Most have a "thumb" on the hind foot, as well as on the front foot. Members of the first sub-order, the Lemurs, and the peculiar Aye-Aye are mainly confined to Madagascar, though some are found in Africa and one in Asia.

The second sub-order contains monkeys and apes, as well as man. Nearly all have the hind "thumb," with a flat nail. Some have no thumb on the hand. Almost all have a convoluted brain. Three families—the baboons, apes. and man—have the same dental formula—$^{2123}/_{2123}$. The higher apes have long arms and short legs, with the soles of the feet facing, and not suited for walking on the ground; they are tailless. Man differs from the higher apes mainly in the more erect posture, the weight being borne entirely by the long hind limbs, and in being "two-handed," with a thumb on the front limbs only, as opposed to "four-handed," with a thumb on each limb. The canine teeth are smaller and the brain of man is much larger and heavier.

PART III.—GENERAL STUDIES.

CHAPTER XXVI.

ROCK STUDIES.

A.—INTRODUCTORY.

The green earth and the rocks about us provide interesting studies. The "sermons in stones" are eloquent sermons; the student who sees "meaning" in sandstone and shale, rounded pebble and vesicular basalt, seldom feels lonely; he has the rocks to read. What story is more wonderful, with its record of past changes? Here, the fine mud of an ancient sea bottom, enclosed the remains of some extinct animal, and is now a hill-top. There, an old coral reef denotes vast changes of land, sea and climate.

"There where the long street roars hath been,
The stillness of the central sea."

Before one can learn geography, he must "see" geography being made to-day. A few years may suffice for great changes in history, and political geography, but, in physical geography, changes are slow—indeed, it was once thought no change was possible, and that the earth about us was so created on Creation Day. Not so. The water from the last shower was muddy as it ran away; in that muddy water lies the story of much of the earth.

To some poets, the hills are "everlasting," but that is false; in time, the muddy stream removes the mountain—

"The hills are shadows, and they flow,
From form to form, and nothing stands."

The causes of these ceaseless changes lie within the earth itself. At a depth of about three feet, the daily temperature is constant. At about sixty feet, the plane of "constant temperature" is reached. Going deeper, the temperature, owing to the internal heat of the earth, rises about one degree for fifty-two feet—that is, 100 degrees hotter for a mile; at ten miles, 1000 degrees hotter; while at twenty-five miles the temperature would melt surface rocks.

While temperature liquefies rocks, the pressure of the overlying mass hinders liquefaction.

According to some, pressure wins, and the center is solid. The specific gravity of the earth is between five and six, that of surface rocks is usually under three; the center material is therefore denser. Above the surface is an ocean of gas, the atmosphere, not yet cooled to the liquid state. The water ocean (hydrosphere) has cooled to a liquid, and probably once encircled the earth to a uniform depth of about two miles. When ores are fused, heavy metals sink and earthy, stony matter rises as slag. The earth is composed of two portions—the outer earthy stony lithosphere (Gr. *lithos*, a stone), and the interior, containing much heavy metal, mostly iron and nickel. There are, therefore, the four spheres—(1) atmosphere (gaseous), (2) hydrosphere (liquid), (3) lithosphere (stony and earthy), and (4) barysphere, the heavy interior.

The theory of a solid center might hold if the earth was once solid, and pressure was preventing liquefaction; but the earth was probably originally gaseous, and the problem is liquefaction from the gaseous, not the solid, state.

Gases liquefy either under increasing pressure or lowering temperature; generally both are employed together. Each gas has a certain "critical temperature" above which, no matter what the pressure, it cannot liquefy. Some scientists claim the center is above the "critical temperature;" and, though the pressure is enormous, the center cannot liquefy. Therefore, a theory of a gaseous center is widely accepted. The earth, like all hot bodies surrounded by a colder medium, loses heat. As it cooled, a crust formed.

> ". . . . They say
> The solid earth whereon we tread
> In tracts of fluent heat began."

The first rocks were formed by cooling from the molten state, and are often called *primary** or igneous rocks. The crust became cool enough for water to remain on it, and the earth was covered by the surrounding ocean. The center lost heat and shrank. The cool crust could not

*The word "primary" is sometimes used also to denote rocks formed in the Primary or Palæozoic Period.

shrink, and slowly settled on the shrinking center. The inelastic, corky skin of an apple, when the center lost water, wrinkled to fit the smaller center, so the earth's crust wrinkled. The high parts formed mountain ranges and the broad upper parts, the continents; while the deep downfolds formed the ocean basins.

On emerging from the protecting waters, the land was attacked by the many forces of nature. Rains carried away a part; winds blew fragments: the sun shone on the rocks, and they expanded; they cooled at night and contracted; the expansion and contraction loosened pieces. Water entered cracks and froze, expanding much and forcing off blocks. While the land is below the protecting waters, it is safe; but, once it projects as a hill, it is attacked by the full battery of nature's weathering forces. The earth is probably wrinkling to-day, as the crust slowly settles on the shrinking center. Volcanic outbursts and earthquakes are probably evidences of a wrinkling crust.

As the rocks wrinkled, molten plastic material was squeezed up amongst them, and some, reaching the surface, flowed over the surrounding country. The surface-spread material cooled rapidly. The deeper parts intruded into the overlying rocks cooled slowly under great pressure, allowing the rock minerals to crystallize in fair-sized crystals. This deep-seated rock is composed of grains: it is a granitic rock. The surface cooled rock is generally fine-grained. Sometimes a mass shot out, cooled quickly, or the upper or lower surface of a lava flow cooled before the material crystallized, and a "glass" resulted. From the same mass, according to conditions of cooling, there could arise three distinct forms:—(a) *granite* (160: 1), minerals in crystals or grains—formed deep down by slow cooling under enormous pressure; (b) a lava, surface-cooled rock, crystals forming in a glassy ground mass; (c) a glass, formed by rapid cooling. A division of primary rocks into deep-seated and surface rocks is useful. The deep-seated rocks are called *plutonic* (Pluto, the god of the Underworld), and surface rocks, *volcanic* (*Vulcan*, god of fire).

Standing on the granite hill, think of the thousands of feet of overlying rock that ensured proper conditions for crystallizing. Where is that material now? Look for the

answer in the muddy stream, river flood-plains, great low-lying plains, and further on the ocean floor. Yes, changes have taken place, and the granite, though hard, is doomed to destruction until the unceasing, tireless, hasteless, forces of denudation have levelled the country.

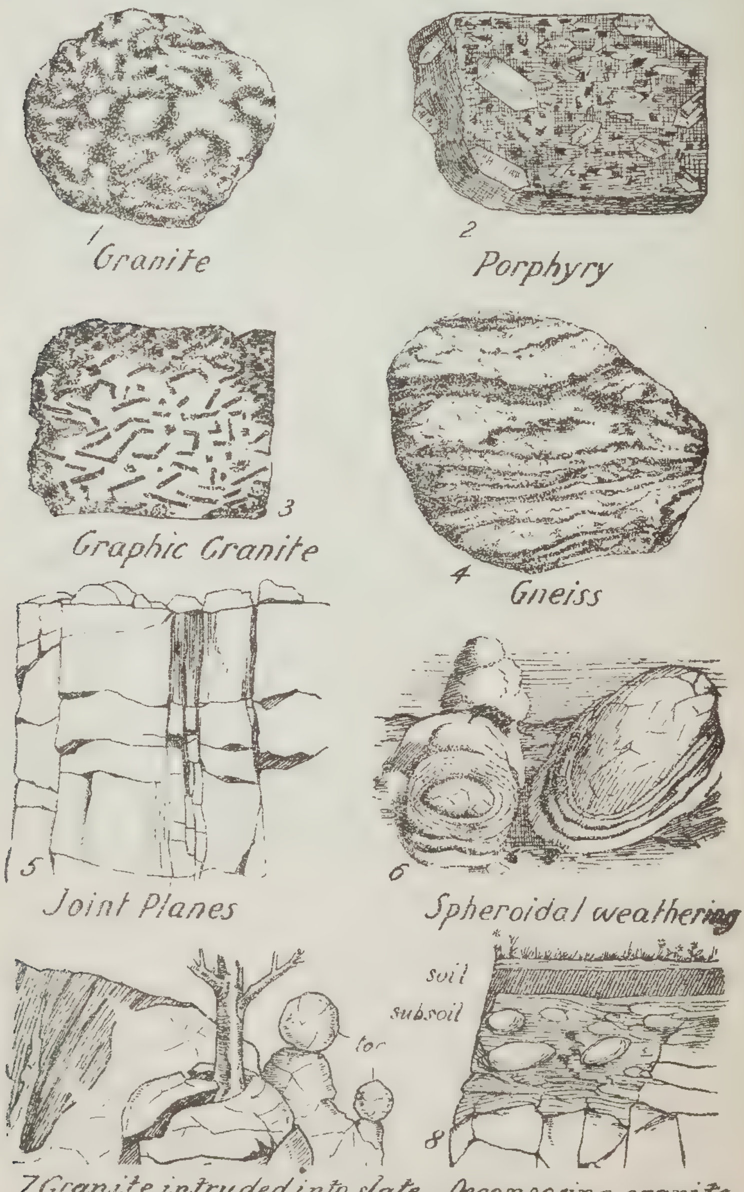


PLATE 160.—ROCK STUDIES (GRANITIC).

B.—GRANITIC ROCKS.

On examining granite on a hillside, three different kinds of grains are seen. Break up a crumbly piece, pick out the white, pink, or grey opaque mineral. It is sometimes a four-sided prism. This is *felspar,* or feldspar (*feld,* a field; *spar,* a common name for non-metallic minerals), an important rock-forming mineral. There are several felspars.

Now pick out the glossy mica, noticing how easily it splits into scales; some granites have white and black micas.

Next pick out the glassy-looking quartz, silica. This though crystalline is, in granite, usually not in its proper crystalline form, a six-sided prism terminated at one or both ends by a six-sided pyramid. It fills the spaces between the felspar and mica crystals, and evidently crystallized last. It is hard and cannot be scratched with a knife.

Sometimes granite shows crystals of two sizes (160: 2). It is then called a Porphyry. The large crystals formed at a great depth; a movement then carried the mass nearer the surface, and crystallization was completed under less pressure, though great enough for the mass to crystallize.

When quartz and felspar crystallize simultaneously, the rock looks as if Hebrew characters were written on it; this is "graphic granite" (160: 3)

Occasionally the minerals felspar, quartz, and mica are in bands (160: 4). The rock is then a gneiss (*nice*).

Search for evidence of change in the granite. Find a piece you can crumble between your fingers. Notice the crystalline lustre of each mineral in a fresh piece. Break off some pieces exposed to the weather. The dull felspars have lost their lustre; rusty stains may be seen—iron stains due to the decay of felspars and micas.

Rain water, with carbonic acid gas in solution, attacks the complex felspars, which contain silica united chemically with potash, soda, lime, iron, alumina, etc. The carbon dioxide unites with the potash or other substances, and is dissolved out, allowing the rest to crumble.

See a big, roughly-spherical block (160: 7) left standing. Why? Evidently it is harder. Running through the granite is a definite series of cracks—joints (160: 5). The shrinking mass cracked at intervals much as the mud of a drying dam does. These cracks are roughly parallel,

and have often a controlling effect on the scenery resulting from the wearing of a block of country. The vertical sides of the Werribee Gorge are determined in part by joint planes. The Buffalo Gorge 1400 feet deep—is due to the parallel joint planes. The Horn on Mt. Buffalo is also due to the same set of joints. There are usually two parallel vertical sets at right angles to each other, as well as a horizontal set. They divide the mass into roughly cubic blocks. If the joints are close, the rock is not good for building stone. If at some distance, they are helpful to quarrymen. Trace the widening of these joint planes until separate blocks are formed.

Now think of a cubic block. The sun shines on it by day, it expands; at night, it contracts. Particles are loosened, especially at the corners and edges, and the block is rounded off. Find many fragments at the base of the rounded boulders, so typical of granite hills.

Note the pieces like part of the coat of an onion breaking off a boulder. The center of the block is harder (160: 6), and granite typically flakes off as it weathers—a form of "spheroidal weathering." *Exfoliation* is the term applied to this leaf-like weathering. Rocking stones and tors (160: 7) result from this peculiar weathering. They are monuments of a mass removed. They are formed where they are, and have not been carried there. Water soaks into the cracks and joints. When freezing, it expands irresistibly one-tenth of its volume, and the rocks are riven asunder. Note at the foot of a cliff a slope of fragments, a "talus" (176. 1). The practically indestructible quartz is a simple compound of silicon and oxygen—silica, and does not decompose.

Where are the remains of the felspar and the mica from the missing granite? Follow down the nearest water-course. Flakes of mica abound; having much surface in proportion to its bulk, mica is carried far.

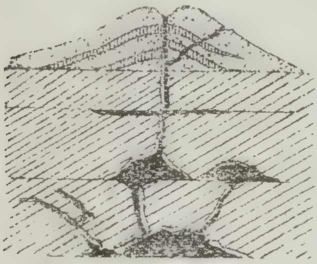
The felspar, when one part dissolved, crumbled into a fine material usually called clay. It is a thought strange to many, perhaps, that much of the clay so common everywhere was probably derived from felspars. Kaolin, pure china clay, is so derived. The fine material may travel far; look for it in a region of little slope—an area of deposit,

for, while the water has even moderate velocity, this material is not deposited. Much of it reaches the sea.

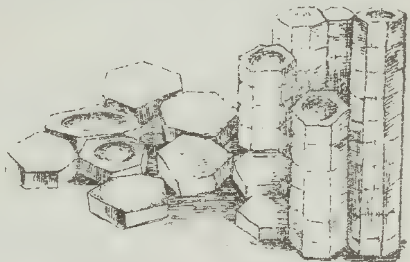
Some granites have black patches. These contain iron and magnesium, and separated out first. Such patches are called segregation patches (contrast with "congregation").

C.—VOLCANIC ROCKS.

Think of that hot, imprisoned center. Perhaps a steady sinking of one part presses on the plastic mass. Immediately there is a counter-balancing press up elsewhere. A



1 Diagram of Volcano

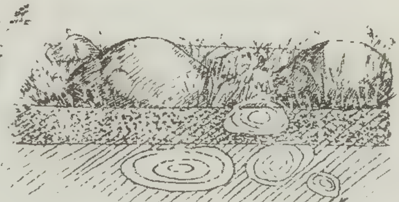


2 Columnar structure

3 Ropy structure

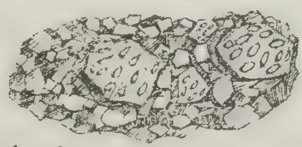
4 Spheroidal structure

5 Stony Rises type



6 Basalt boulders

7 Volcanic Bomb



8 Agglomerate (Volcanic Breccia)

Plate 161.—ROCK STUDIES (VOLCANIC).

weak spot is found, perhaps on a plain, or even under the sea. The water contained in the rock, under great pressure, flashes into steam, forces its way up, blowing out what is above it, and constantly blowing off fragments. These drop, forming a hill round the vent. Anon, perhaps, the molten mass within wells up and flows over the adjacent country in a sheet of molten rock—a lava-flow. A discharge of fragmentary material may be succeeded by another lava-flow. A rain of fragments—scoria (162: 1) and volcanic dust—may build up a mountain. At the beginning, this was as much a volcano as at the finish; it was not a mountain then. Some volcanoes discharge mud, some lava, some volcanic dust, and some water only. A volcano is sometimes said to be "burning." Burning means usually the union of fuel with oxygen. Fuels are mostly carbon or carbon compounds. There is usually no carbon in a volcano. Further, for "burning," oxygen is necessary. With the great uprush of steam, there is no supply of oxygen, and no burning. Smoke is mostly unconsumed carbon. As there is no carbon there is no real smoke. The so-called smoke is water vapor in clouds, with much dust. The flames are the reflection of the molten rocks beneath on the watery vapor above. A volcano is a vent through which water, steam, lava, dust, etc., are discharged.

Western Victoria is one of the great volcanic areas of the world. The pressing down of Bass Strait and Port Phillip Bay possibly caused eruptions at many points to the northward and westward. Lava, unlike granite, is fine-grained; a microscopic examination of a thin slice shows that the rock is a felt-work of narrow crystals in a ground mass of glass, forming a tough rock suitable for road-making. Its rapid cooling was unfavorable for crystals However, there may be an occasional crystal, formed probably when at lower depths under pressure. The rock was then forced up and poured out at the surface. Large felspar crystals and green olivine may so occur.

Most Australian lavas are rich in lime-iron-magnesium minerals. The iron gives a dark color, as in bottle glass. The dark basic lava is basalt, often called bluestone or blue metal. The magnet will pick up dark grains of magnetic iron oxide (magnetite) from crushed basalt (bas′-alt).

The next point is that the lava often has holes (162: 2) in it. Compare with bread. Dough is put in a warm place to rise. The carbon dioxide from the yeast expands, causing many gas cavities. The molten rock welling up from below often has water disseminated through it. Approaching the surface, the pressure lessens, the water expands into steam producing cavities or vesicles in the rocks. The rock is now a "vesicular basalt." Sometimes elongate vesicles show the rock flowed on after they were formed.

PLATE 162.—ROCK STUDIES (VOLCANIC) AND AUSTRALITES.

Illustrate the flashing into steam by lowering the handle of a soda-water siphon, thus releasing the pressure; carbon dioxide dissolved in the water (of course, there is no soda in it) under pressure, separates out. See bubbles appearing from the water, as the gas, escaping violently, often scatters drops around, as when a seidlitz powder is mixed. The "superheated water," flashing into steam, bursts the rocks asunder, reducing the pressure still further, and allowing further explosions and scattering of fragments. Some volcanoes, having little steam, are free from explosion. The lava cools as a compact rock.

Some bits blown out may rotate rapidly, and form "volcanic bombs" (161:7), which have often two long processes representing the axis of rotation. The fine fragments often form beds of well-stratified rock (tuff). The coarse fragments (often some are vesicular) form "volcanic" agglomerate (161:8).

In cavities there are sometimes white, rounded masses (162:3); sometimes beautiful tufts of long, glistening crystals: at others, crystals in considerable variety. Some call these "congealed water," recalling the ancient idea of a quartz crystal — that it was water so frozen that cold had got into the heart of it, so that, even if put in a fire, it would not melt again.

These minerals separate from percolating water, but are not congealed water; many are carbonate of lime. Water containing carbon dioxide in solution penetrates the rocks, and dissolves lime. When it reaches a cavity, some carbonate of lime is left. Break a rounded mass, and see the concentric layers built up by deposit opposite a point where the water entered, sometimes until the cavity is filled.

Occasionally these masses are formed of silica, which weathers less readily than lava, which has white, oval, rounded masses (162: 3) standing up on it. This resembles almond toffee, and is called *amygdaloidal lava* (Gr. *amugdale,* an almond; *eidos,* form). Agates (162:4) and other beautiful minerals are sometimes similarly formed.

The carbonate of lime (Aragonite) sometimes crystallizes in beautiful tufts of radiating, needle-like crystals (162:6). Calcite (162:5) is another form of crystallized carbonate of lime. When transparent, it is called Icelandic

spar, and shows double refraction well. Other minerals are Zeolites, which are often of great beauty. The Melbourne lavas are famous for their beautiful zeolites.

The lava mass being liquid would flow along the valleys (162: 7, 8). In some cases, valleys were filled, ridges covered, and the country was levelled off to a plain, sloping from the volcano. The lava soon cooled and partly solidified on both upper and lower surfaces; still it would flow on, giving a characteristic pulled-out "ropy" appearance, "ropy structure" (161: 3).

The lava mass consolidates often round hard centers (161: 4, 6); as seen in some road or railway cuttings. Between the different spheroidal masses, the material decomposes more rapidly as waters soak through, removing some material and allowing the rest to crumble.

On the surface, this softer material is washed or blown away, and the hard parts project as "basaltic boulders" (161: 6). In other cases, the appearance of roses, cabbages, and onions, is produced where the blocks are small and the harder centers are close together. "Onion structure" and "spheroidal structure" are names used for this.

In other places, where the cracks due to shrinkage are vertical, the lava forms columns (161: 2). The usual explanation is that the lava probably flowed into water, or a swampy part. The rapid cooling caused rapid shrinking, producing vertical cracks at right angles to the cooling surface. The cracks generally form six-sided prisms, or columns, and they can be compared with the cracked mud of a dried-up pool or dam. Many examples of columnar basalt are known; the Giant's Causeway (Ireland) is famous.

"Stony Rises" are a remarkable feature of some lava flows. The lava is in large blocks (161: 5), as if cut by masons. The lava has apparently separated into this striking form while cooling. The edges are often square and sharp, and the stacks seem as if built by human agency.

The lava, as the rock decomposes, forms a rich, generally sticky, soil. In a road cutting, the formation of soil from the solid rock (162: 9) through the stony subsoil, to the soil almost free from large rock fragments, can be traced. Granite (160: 8) shows a similar passage.

Australites (162:10) are peculiar bodies figured about natural size. Some authorities have regarded these as of volcanic origin, but the more generally accepted opinion now is that they are of meteoric origin, meteors fallen from the sky. Some are dumb-bell shape, some have a rim round a denser biconvex mass.

D.—SEDIMENTARY ROCKS.

When the original rocks projected from the encircling waters, they were attacked by the forces of denudation, and, in due time, worn down. The material, sediment, derived from these igneous rocks was carried to lower levels, and spread out in layers as sedimentary rocks.

The sand was dropped close to and on the shore, the mud and clay farther out, but still comparatively close to the land. Storms stir the muddy waters. The coarser material is piled on the beach, and the deposit becomes finer as the shore is left. At the distance of about 100 miles, little land material is deposited on the ocean floor. This is surprising to beginners; no sand on the ocean floor away from land! The sand is derived from the land, as the sea cuts back the cliffs, or from streams. The clay and mud are deposited farther out, forming beds of mudstones and clays, and covering animal and plant remains.

Farther out still, in the clear-water, sea animals leave their shells and skeletons, to be covered by successive generations, which, in turn, are covered and preserved in beds of limestone. The Great Barrier Reef, beyond the reach of land material, is composed of animal and plant remains.

Farther still from land are deposited the skeletons of the few animals of the bottom and lower waters, and tiny fragile shells and skeletons of animals inhabiting the surface water in countless numbers. Their remains form "oozes." Farther out still, not even these minute shells are deposited. Slowly sinking, they are dissolved by sea water, and only the slight amount of earthy "ash" remains, perhaps forming the fine red clay deposit of the deepest ocean abysses. As water is practically incompressible, the specific gravity is almost the same throughout. An object sinking at the surface sinks to the bottom.

If nothing further happened, the land would be a gently sloping plain (peneplain), down which the rain-water flowed slowly to the ocean. But two other changes take place. First the crust is wrinkling to fit a shrinking center. The wrinkling produces the fold mountains, so imposing and so difficult of access. Probably, at several different periods, fold mountains have been formed, only to be steadily removed by water action. Again, after long periods of rest of the crust, but slow shrinking of the center, the

PLATE 163.—SEDIMENTARY ROCKS.

former has again collapsed and settled down until equilibrium was restored; still again wrinkling has taken place.

The Australian fold mountains represent an ancient wrinkling before the coal plants of the true coal period flourished.

Australia took little or no part in the last wrinkling, when the Andes, Atlas, Alps, Carpathian, Caucasus, Himalaya, and other high mountain ranges were formed.

Secondly, other regions, instead of wrinkling, may break in long lines (faults), and one side may slowly sink. Land masses have probably broken up, and parts have sunk and disappeared beneath the insatiable sea. The southerly connexion of Africa and Antarctica, of Australia and Antarctica, of New Zealand and Antarctica; the connexion of Australia and New Zealand, Australia and Africa, of Africa and South America, of Europe and America, have gone.

On a smaller scale, regions sink on one side, leaving bold edges of the higher lands. In fact, the deeper one edge sinks, the higher the other tends to be forced. It is a rule in this wrinkling and subsiding, that the greatest depths are opposite the greatest heights. Thus are formed a type of mountain called "block mountains." The Pennine Mountains are of this type. Probably the Otway Ranges in Southern Victoria represent a block left at a higher level, while the bottom of Bass Strait and Port Phillip Bay has subsided, causing the volcanic outbursts that produced the great western lava plains and many extinct volcanoes.

Again, there are upwards of five miles in vertical thickness of gold-bearing sandstones and shales in Victoria. From what has been said before, sands and clays are shallow-water sedimentary rocks, deposited in the sea at about the same rate as the land was sinking. We can understand how it is possible to get beds of sediments—sandstones, clays, mudstone, and limestones 20,000 feet thick, and yet deposited in shallow water perhaps less than 200 feet deep.

The slow rising and sinking suggest that the earth's crust is in a state of delicate equilibrium. Imagine two blocks of the earth's crust side by side with a slight slope from A to B, so that water runs on to B. Running water carries sediment, which is deposited on B. B slowly sinks, while A, being lightened, rises, so that, corresponding with the subsidence and deposition of sediments on one block, there is the

uplift and denudation of the other. It has been well said that unlift provides the block of marble, while denudation is the sculptor carving the scenery so varied and beautiful.

In England there is much chalk, some of it famous as the white cliffs of Dover. This chalk consists largely of

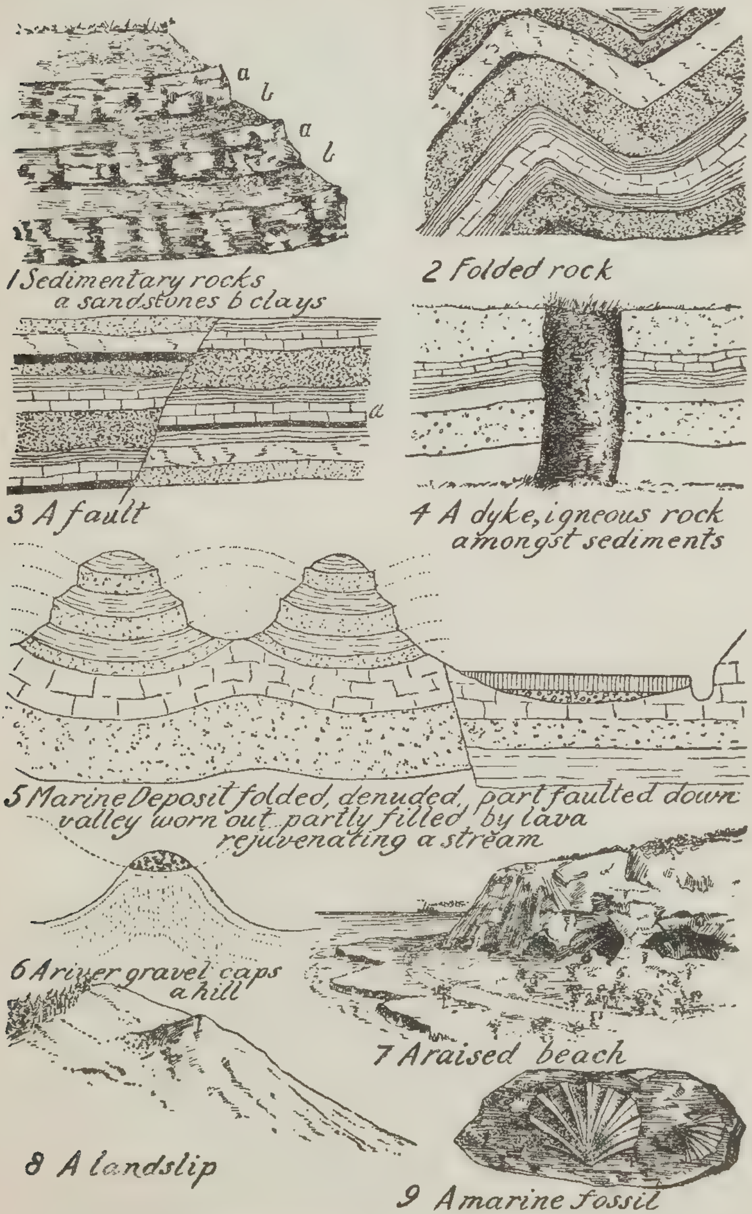


PLATE 164.—EVIDENCE OF CHANGE.

the tiny shells of animals of the surface waters. The sea about what is now England was then probably at least 1,000 fathoms deep. There is is no admixture of sands, clay or land material in this deep-sea deposit. The same deposit (ooze) is forming now on the bed of the Atlantic Ocean. An inch a century is probably an extravagant estimate. Yet the chalk attains a vertical thickness of 1,700 feet. Think of the time (over two million years) required to form it. It is, however, little use thinking in years. We must allow vast periods of time; any change, no matter how vast and incredible it may seem, becomes possible.

Establish that, under every water surface, material is being deposited. Dig a small lake on a runnel. See the delta (163: 1) formed where the stream enters the pool. There is no slope, the velocity is checked, and the stream drops its load.

The coarse material is dropped first and the finer material farther on. The material is sorted (163: 1, 3).

Follow a little stream; note the big stones in the upper parts, close to the source of supply of rock fragments. These are angular. The material gets finer and more rounded down the stream, until, at the mouth, generally no stones are found. On the beach, the boulders are close under the cliffs yielding rock fragments as they are undermined by wave action. Currents and tides sweep the finer materials along the shore. Storms stir them up, grinding them down, piling the coarsest material on the beach, and gradually working the finer material farther out.

Railway or road cuttings, and quarries or creek-sections afford opportunity for examining the rocks. Any bed of material, whether hard or soft, is called a rock; a bed of loose sand is as much a "rock" as is a mass of hard granite. The angular materials being cemented (163: 6) form a breccia (*bret'-she-a*); the rounded stones form conglomerates (163: 7), or puddingstones (163: 7). If the cutting is in old rock, several points can be readily studied.

First, the rocks (164: 1-5) are in layers, strata. In many places fossils (164: 9; 166: 1-10), remains of marine animals, show that these are marine deposits.

Some layers feel rough (164: 1a); the grains of sand can often be seen. Generally, the sandstones are thicker than

the others. The thinner layers are composed of fine material, clay mostly, deposited farther from the shore in slightly deeper water. Rarely beds containing stones are present. These indicate proximity to the ancient shore or an old river-bed, for heavy stones are not moved far by currents and tides. They have often been cemented together by one of Nature's cements, iron, lime, silica, or clay; some have been pressed and hardened when the earth wrinkled; some have been baked and altered by the intrusion of granite or of dykes (164:4), changing the loose sands into sandstones and quartzites, and the clays and mudstones into shales, slates (163:8), and schists and limestones into marble. Thus are formed "metamorphic rocks," intermediate in texture between igneous and sedimentary rocks.

But you say, how do you account for beds of sand (164: 1), both above and below layers of clay, if sand is deposited closer to the shore, and clay farther away?

The whole series (164:1) is a shallow-water deposit, and shows that the land slowly subsided at about the same rate as the material was deposited. Still, there were probably small oscillations of level, an area rising a little, that is, getting nearer to the shore, and again sinking. So that, besides telling of marine sedimentation, the strata probably indicate alternations of level. Sometimes the alternations of sands and clays show different conditions of deposit.

The next point is: If the layers were deposited on the seafloor, they would necessarily be nearly horizontal; then how is their present position accounted for? Some layers are nearly vertical; most are inclined. At one end of the section, perhaps, they slope steeply into the ground; at the other, they slope in the opposite direction. Having been wrinkled since they were laid down, they afford evidence of a shrinking center. Many gold-fields are associated with these folded rocks. The rocks at one place may slope down, "dip" to the east, and, at another spot some distance away, to the west; you can imagine the layers continuous right across. They have been worn off, leaving the edges standing up, often suggesting books on a library shelf.

The old fold mountains have gone, being mostly planed off by running water. For most of the layers, sloping up, since they were once continuous sheets, there is a corre-

sponding layer sloping down farther on. If the rocks are sharply folded, the corresponding layers are near; if gently folded, some distance away. Some layers may be broken and displaced. Such a break is a "fault" (164: 3). Faults are important in mining. Imagine a miner is following a bed of coal or a band of gold-bearing rock. At the fault, the band is lost. To find it, a rule which holds in most cases, since one side has generally slipped down, is "follow the larger angle." Test this (164: 3) by following first the layer on one side, and then on the other.

Another feature often plainly seen in older rock is the series of parallel cracks, joints (163: 4), running through them. These often break the mass into cubic or rectangular blocks—"natural bricks."

Often along these joint planes, drainage waters travel. They carry iron in solution, and may deposit this among the sand-grains bordering the cracks, firmly cementing them, and forming a harder piece (163: 9) than the rest of the block. Hence it is common to get a raised network of ironstone, with the characteristic rusty color round the block, the center of which has crumbled or been cut away by the wind blowing sand round it. In places, this raised network forms beautiful "filagree"; in others the cementing material seems to deposit and grow round centers forming concretions (163: 5) which may suggest spheroidal structure (161: 4).

Again a band of rock or earthy material not in layers may be seen. The stratified rocks at either side are often hard and brown, showing they have been baked and altered. Sometimes the earthy material breaks across the strata.

This is a *dyke* (164: 4), composed of igneous rock, squeezed up through a crack or fissure. Being in the molten state, it baked and altered the adjacent sediments. The dyke rock, when fresh, was hard and dense; but it contains many complex minerals, which are attacked by acids. Parts of them were carried away in solution, and the rest crumbled into a fine, clayey material. Though the bluestone is more durable mechanically, as can be shown by rubbing bluestone (basalt) against sandstone, yet it is more rapidly acted upon chemically, and, much sooner than the practically insoluble sandstones and mudstones, it weathers away to a soil. Some dykes stand up as walls (hence the name),

where the surrounding rocks are soft, and have been worn away, but other dykes, crumbling rapidly, form hollows.

Often colored clay has white streaks running through it. These are due to the dissolving out of the iron. The decay of the vegetation growing on the surface produces certain acids. The surface water percolating down carries these with it. They dissolve out the iron, and often other minerals, and leave a white clay.

When a country is worn by water action, the original up-folds and down-folds do not long remain as the hills and valleys. The up-folds are often stretched, and the strata are cracked across, providing weak places where the water cuts in quickly. The down-folds are usually compressed and compacted, and resist wearing. Usually the up-folds become the valleys (164: 5), and the down-folds the hills. The Jura Mts. are thought to be very young mountains because the original up-folds are still the mountains, and the down-folds, the valleys. In older mountains, as foretold, the valleys have been exalted, and the hills brought low.

River gravels may be cemented by iron-rust borne in the water and deposited amongst the stones. The old river-gravel would now be harder than the adjacent country. Subsequently the cemented river-gravel would be left capping (164: 6) a hill. Similarly, lava (being liquid) flowed along the valleys, covering and burying the river gravels. The lava, being hard, persists, and the present valleys (162: 7, 8) are worn round the outer side of the lava-flow (164: 5). Miners search for these buried river gravels.

In wet weather a part of the hillside may slowly settle or sink as a land slip (164: 8). Later this would be a round swelling under a break, a steep part of the hill. Often grass removes all trace of a wound or scar, but the rounded mass and the change of slope above it suggest a landslip. In inclined strata, if a soft, clayey layer has much weight of rock above it, there is risk in a wet winter that the rocks may slip down. By driving in a pipe and allowing the water to escape, serious damage is sometimes prevented.

A raised beach is also a further evidence of change. Either the sea has gone back or the land has been uplifted, that is, a positive movement of the land relative to the sea has taken place. The rounded stones on the old shore-line

or the level ancient shore-platform (164:7) suggest the "raised beach."

A marine fossil in the rocks (164:9) is also clear evidence that that rock was formed under sea-water, and that great changes have taken place.

E.—LIMESTONE.

Sea shells are mostly made of carbonate of lime, carbon dioxide and lime. The remains of sea animals form beds of limestone; some may contain much sand and clay.

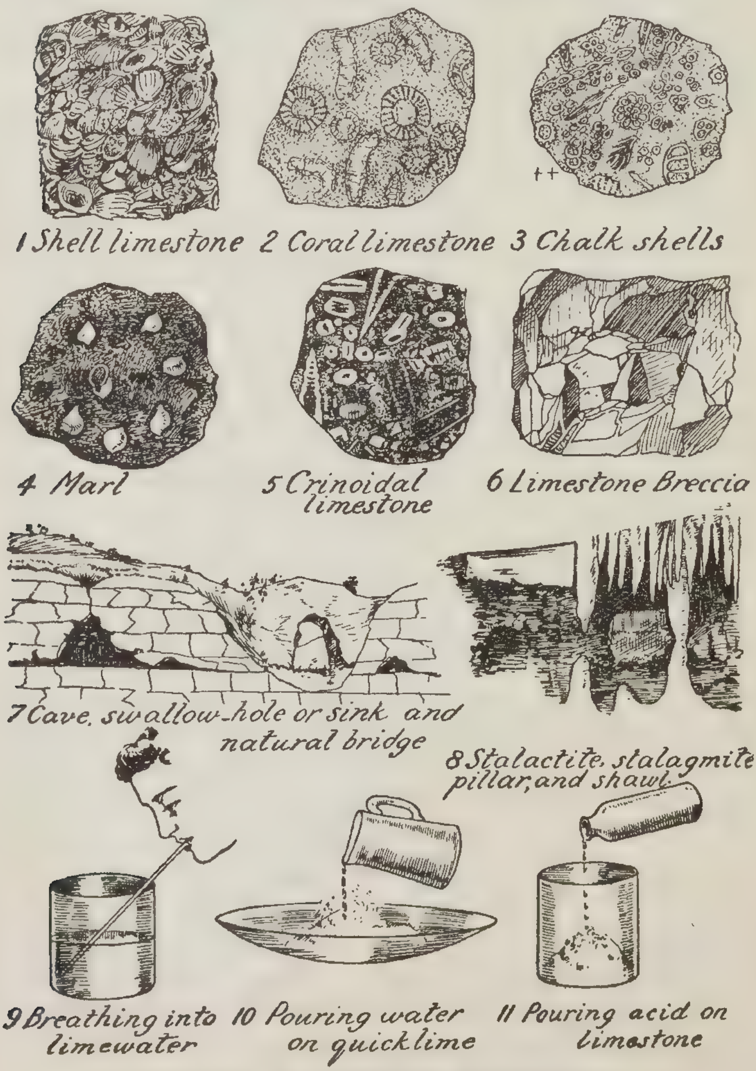


PLATE 165.—A STUDY OF LIMESTONE.

Some limestones (165: 1) are made of shells of cockles, mussels and other sea shell-fish (molluscs). Some are coral limestones (165: 2), or are composed of the stems of sea-lilies, crinoids (165: 5), relatives of the star-fish. Some, *e.g.*, chalk, a very fine limestone made of the minute shells of tiny floating animals of a deep sea. These form an ooze (165: 3); a fresh water impure limestone is a marl.

Sometimes the limestone has been shattered by earth movements and recemented as a limestone breccia.

The lime is dissolved in seawater as lime sulphate; carbon dioxide from the breathing of animals unites with the lime and forms the less soluble limestone.

Rainwater, with carbonic acid gas, in solution readily dissolves limestones (carbonate of lime), forming bicarbonate of lime, which is soluble in water and is carried away. As the water soaks along the cracks, it dissolves some limestone, widening out the cracks and forming cavities and caves. On exposure to the air, some carbonic acid is given off, and some soluble bicarbonate of lime returns to the insoluble carbonate of lime, and is deposited. Thus water dripping from a point constantly adds to it, and it grows down (165: 8) as a "stalactite." When the drop falls to the floor, more carbonic acid is given off, and more carbonate of lime is deposited as a "stalagmite," building upwards. (*C* comes above *g* in the alphabet, and stalactite comes above stalagmite). Sometimes the stalactite is large, and the stalagmite small; sometimes a small stalactite is connected with a large stalagmite. Often the stalagmite forms a sheet on the floor, burying bones and other things.

If stalactite and stalagmite meet, a "pillar" is formed. If instead of dripping from a point, the water is exposed along a crack, a "shawl," a narrow long sheet, may develop. Occasionally a band discolored by iron is deposited, and the structure becomes a "blanket," with parallel darker lines.

Wild animals, including primitive man, often lived and died in caves. The bones, and remains of food, preserved under the layer of stalagmite, are much sought as fossils.

Drainage water finds its way along cracks, and widens them out. It dissolves out the lime, and the surface soil sinks into funnels, often many yards across and resembling craters; these are sinks, swallow or run-away holes (165).

Sometimes the roof of a cave collapses, and the whole cave may disappear, except perhaps one section of the roof, left as a "natural bridge" (165:7). Some limestone regions have no surface water; it flows underground.

In conducting a study of limestone some experiments should be performed. Chalk (limestone) is composed of carbonate of lime, which can be formed by breathing into limewater (165:9). Water poured on quicklime combines chemically with it, forming slaked lime. This chemical union is accompanied by the giving out of much heat, so that rain on uncovered bags of quicklime often sets buildings and railway trucks on fire.

Acid poured on limestone (165: 11) causes effervescence or the giving off of a gas (carbonic acid gas).

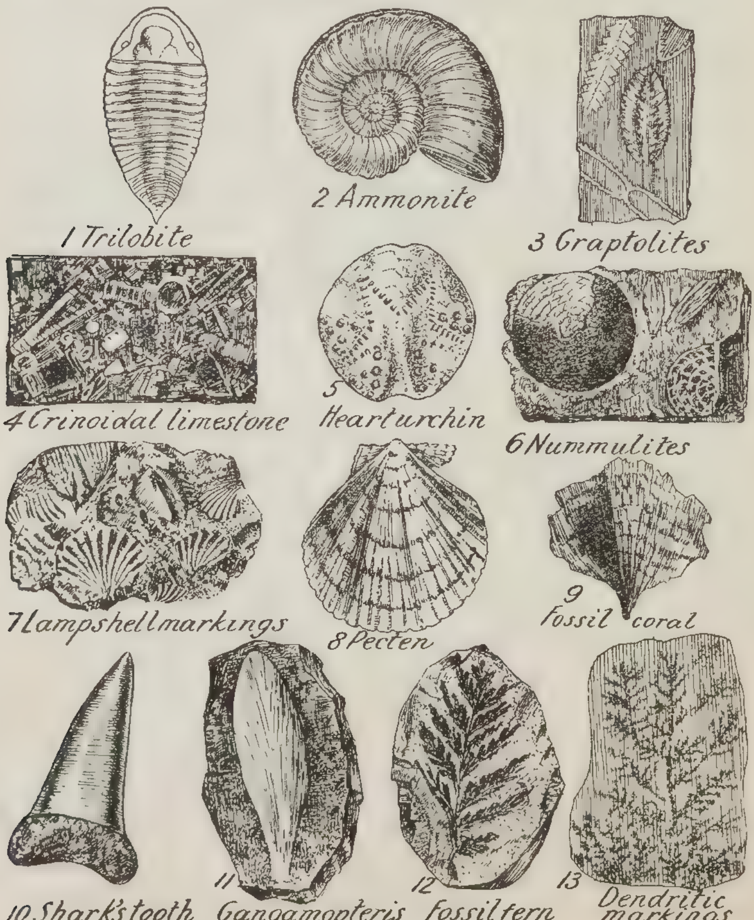


PLATE 166.—FOSSILS AND DENDRITES.

Limestone is burnt and the carbonic acid gas is driven off; quicklime is left. Water added to this forms slaked lime. Carbonic acid breathed into slaked-lime solution produces carbonate of lime (limestone). If a double quantity of gas is given, bicarbonate of lime is formed, and this, being soluble, dissolves in the water.

F.—FOSSILS.

Fossils, "nature's medals," are of great importance and interest to the nature student and scientist. They enable the scientist to assign to its proper period a geological formation. A Roman coin in a bed of clay would show that the bed was formed not earlier than the Roman period.

Characteristic animals lived at each main period of the earth's history. Trilobites (166: 1), with body divided into three lobes, and graptolites (166: 3), whose remains suggest writings, were important in the old period. Ammonites (166: 2) were important in the middle period.

Pectens (166: 8) and other bivalves, and some single corals (166: 9) lived during the recent period. Most of these were marine. Life originated in the sea and land fossils are not abundant in the period of old life, the Palæozoic (Gr. *palaios,* old).

Ferns (166: 11) were important in the coal period and later. Lampshells (166: 7) have ranged from the very oldest periods to the present. Crinoids (166: 4) were very important in the old period. Mantelpieces are often made of crinoidal (166: 4) and coral (165: 2) marble.

Heart urchins, *Lovenia* (166: 5), are extremely common at Beaumaris, on Port Phillip Bay, and on the lower Murray River. Nummulites (166: 6), one-celled animals, whose shells suggest coins or beans, are very common in the limestone of which the Pyramids of Egypt are built.

1. There are three main periods fixed by the contained fossils—1. Palæozoic, the period of "old life"; the fossils are mostly unlike living animals. 2. Mesozoic, the period of middle life. 3. Cainozoic (*kainos,* recent), the period of recent life, the fossils resembling living forms.

Shark's teeth (166: 10) are common in Cainozoic rocks in Southern Victoria. They indicate that those beds were deposited in the sea. A tooth five inches across, possibly from a shark 80 feet long, has been found at Muddy Creek.

Gangamopteris (166: 11), a fossil of great importance to the geologist, is the remains of a land fern; it is found in New South Wales, with coal above and coal below it; at Bacchus Marsh, with glacial deposits above and below it; in India, South Africa, and Brazil. It is an important link in the chain of evidence for the existence of the ancient land-mass Gondwanaland, which included Australia, India, South Africa, and Brazil. Bacchus Marsh is important as showing glacial conditions in a now warm country during the true coal period; many scientists thought that the earth then enjoyed a universal tropical climate.

Fossil ferns are common in the carbonaceous rocks of Victoria, which include the black coals of Wonthaggi and Outtrim. The coals were formed in a great lake that occupied most of Southern Victoria. Rocks of this series are found in South Gippsland, the Otway Ranges, Barrabool Hills, and the Merino Downs in Western Victoria. They are of the same age as the Jura Mountains, and belong to the Jurassic period.

Many people wrongly call plant-like markings (166: 13) common in older rocks, "fossils," "fossil ferns," or "graptolites." These are the beginning of crystal growths, and are formed by manganese or iron minerals settling from solution between layers of rock in forms suggesting plants. They are therefore called dendrites (*dendron*, a plant).

G.—PEBBLES.

A bed of pebbles is a source of interest, and should not be neglected. The bed consists of hard rock fragments, the residue of a mass that has gone. The softer material has been ground fine, and carried on. As one travels up stream, the pebbles become larger and more angular, until at last the cliffs or other sources of supply are reached. Following down the stream, the fragments get smaller and smaller and less angular, until they are beautifully rounded. The stones are not really water-worn; being stirred and moved by water, they wear the corners from one another, and so become rounded and smooth by mutual attrition.

The kind of pebble depends on the material available. In granite districts, on river and beaches, granitic pebbles (167: 1, 2) will preponderate. Porphyry, showing two

growths of crystals, is a variety. Agate pebbles (167: 3; 162: 4) are found in the streams of the metamorphic rocks of the north-east of Victoria, and in other places. The

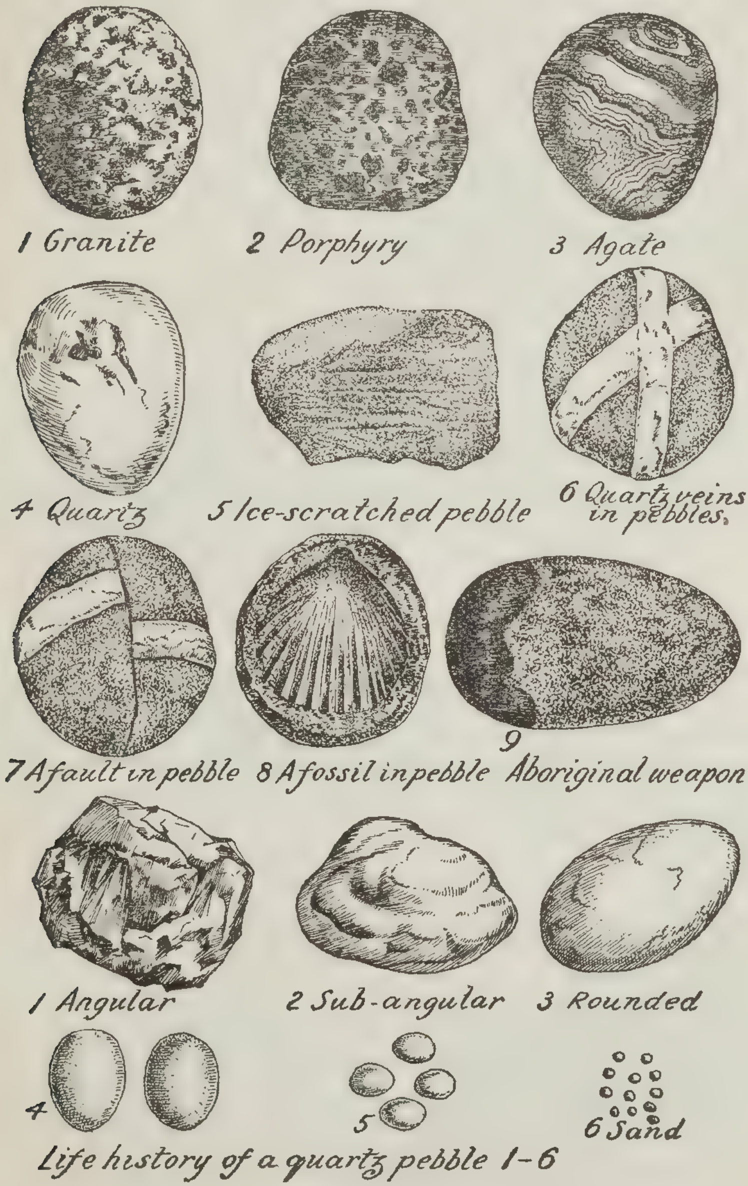


PLATE 167.—PEBBLES.

wavy lines show that the very hard material was deposited in cavities, much as silica is deposited in amygdaloidal basalt, as already described. "Ice-scratched" pebbles (167:5) are common at Bacchus Marsh. Frozen in the bottom of the ice-sheet and scraped over the hard rocky floor, they have become smoothed and scratched; water never scratches. Some pebbles knocked loose, turned over, were again frozen into the moving ice, and again ground flat, smoothed, and scratched, much as sandpaper smooths and yet scratches a fine surface. "Keel edges" between two ground down faces are also characteristic.

Some pebbles have quartz veins (167:7) crossing them. Quartz, as we have seen, is an essential constituent of granite. In addition, it occurs abundantly as veins and lodes penetrating other rocks. Quartz (silicon dioxide) dissolves in very hot water, especially if alkali (soda or potash) is present. These hot solutions, rising along fissures, and becoming cool, deposit some of the quartz as vein quartz. Usually, the percentage of quartz in a rock mass is small.

Next time you stand on a bed of quartz pebbles, picture it in its original situation, veins in country rock. Then regard it as a monument of what has gone, and try to picture the destination of the material removed. The quartz is so hard that no knife can scratch it; it helps to grind away the other rocks, and is itself ground smooth and smaller. The life-history of a quartz pebble (167: 6, 1-6), from original position, through angular, sub-angular, and rounded pebbles to gravel, fine gravel, and sand, can be traced as the material along the river is studied. By the time the river mouth is reached, the quartz may be worn down to silt.

Intersecting veins are sometimes seen. The continuous band is the younger; it was formed in a fissure through the other (167:6). Pebbles often show good examples of faults, a band, *e.g.*, a quartz-vein, may be broken (167:7) and moved, and the whole mass re-cemented. The pebble then would show the fault clearly. Some limestone pebbles (167: 8) contain fossils. Pebbles, being hard, have often been utilized by the aborigines. Choosing a suitable pebble, the blackfellow put (167:9) an edge on it.

CHAPTER XXVI.

SHORE STUDIES.

Nature makes and unmakes; what she builds up to-day, she attacks and removes to-morrow. The ocean, as well as accumulating sediments and building up sedimentary rocks, is a destroying agent. Between tide-levels it batters and wears cliffs and land. In fact, cliffs (168: 1) are formed by the sea as it cuts (168: 2) a ledge at tide level

PLATE 168.—SHORE STUDIES.

into the sloping land. The rocks being of unequal hardness, harder blocks are left as islets (168. 1), stacks, needles, arches, and natural bridges. Caves (168: 5) develop along lines of weakness, and may be connected with blow-holes some distance inland. Projecting points (168: 3) are worn back into cliffs, and the material so derived is swept along the beach, building bars (168: 3) across indentations, so that what the ocean cuts back in one place it builds up in another. The shore line becomes a succession of points wearing back, and of sand beaches building up. Often the built-up beach deflects the river (168: 3) right across to the next high land, where the stream must cross the sand to the sea. If the stream is small, it may be completely barred, and the waters may rise until they burst the barrier and escape suddenly, or they may filter slowly through the loose sand to the sea. Sometimes a considerable lake is formed closed from the sea for long intervals, *e.g.*, Lake Tyers, Victoria. If the rivers flood, they sweep the sand away. If a storm comes on, the bar may again close the lake. Often deep rivers can be crossed by wading the sand-bar at the mouth. The flowing of streams parallel to the beach for miles is a feature of many shores.

Oftentimes islands near the coast are united to the mainland by the drift of material by currents, tides, and waves; they become "tied islands."

The ocean works mainly within tide levels, so that, as it forms a cliff cut off about low-water level, it leaves a "shore platform." The powerful waves break as they reach this platform, and rush on, losing their force before the cliff is reached. Thus the sea shuts itself off from the cliffs it is attacking. The wider the shore platform, the less the wearing effect on the land. In a few places, *e.g.*, Port Campbell, on the coast of Victoria, very soft rock below the low-tide level allows the sea to keep attacking directly on the cliffs, and there is no shore platform. Here the waves will be able to cut back for considerable distances, but such cliffs are rare. Usually the shore platform, "plain of marine denudation," is present, and is not extensive.

The sea may recede or the land may rise, producing a positive movement of the land relative to the water; shore platform and beach ledge then denote a "raised beach."

CHAPTER XXVIII.

THE ACTION OF WIND.

Wind is a most important agent in a dry country in the wearing away of land surfaces. A "sand blast" wears glass, as in etching, "smoking," or "ladies" on the windows of railway carriages, so the wind-driven sand on the beach etches glass (169: 9) or grinds pebbles flat (169: 8), and in Central Australia polishes the ground until it may shine like an earthenware teapot. Sand grinds away steel, as when an axe is sharpened on a grindstone.

Sandhills (169: 1) are common features of the dry, loose, sandy region along the seashore. They form wherever the soil is loose. The north-west of Victoria and Central Australia have great sandhills; once this was thought to be positive proof of an inland sea. The wind strips off good soil, and blows it for miles. It is important not to interfere with "cover" on exposed positions. Marram grass has been extensively planted, and has proved a good sand-binder. The true Spinifex is an excellent sand-binder, and may be seen on most wild, sandy shores. Drifting sand has covered houses, churches, forests, and rich lands. Years after the surface may be broken, the wind-swirled sand-grains cutting out honeycomb structure (169: 7) on a small scale, or, on a bigger scale, cutting a basin and removing material, forming a sand-blow.

The naturalist always examines sand-blows on a coast. The sand and soil have been removed, all bones, native weapons, stones, shells, etc., remain, thus concentrating, by "dry blowing," the relics of ancient life, human and otherwise. Kitchen middens of the aborigines are often exposed, and axes, knives, and other weapons may be collected.

Rock pillars undercut at the base by sand blowing along the ground are common features of wind-swept country.

But wind builds up rocks as well as removes them. The sand is swept along filling hollows, and producing a long slope, up which the grains travel, to be deposited over the steep edge of the slope. Many lakes in north-western Victoria have a gradual slope on one side and a steep cliff on the other; these are almost certainly wind-formed lakes.

Water does not scoop out basins; except in potholes, it does not cut below its outlet; a series of basins, unless in limestone country (165:7), is suggestive of wind action

PLATE 169.—WIND AND SAND.

The wind may change, and the layers built up from one direction to-day are covered up by layers from another direction to-morrow, producing current bedding (169:5).

Drifting sand is an expensive agent in Australia; it has filled recently excavated irrigation channels, and has covered roads and railways. Fences are often buried; a third fence has been erected over two fences already buried during the short period of man's occupation. The practice of removing the soil-protecting scrubs right up to the roadside, and even from the roads, is a foolish one, and will yet cause the land-owners much trouble in the dry parts of the continent.

The ascending waters, bearing a little lime, iron, or silica in solution, deposit it as a bed of limestone, ironstone, or chert just below the surface soil, where they evaporate.

The soil surface, having been cleared and loosened, is removed by the wind, and the area has become a bare rock-surface of little use for any of man's activities. In other places, a hollow or brush and scrub have caused a deposit of possibly one or two feet of the rich, wind-blown soil. Some fine crops were grown on such soils deposited during the sand-storms of the 1902 drought. Desert soils, if given water, are usually rich.

CHAPTER XXIX.

THE ACTION OF RUNNING WATER.

A.—THE CYCLE OF EROSION.

Running water is the great agent in producing scenery and effecting changes in the earth's surface. Slopes differ, rocks differ in hardness and toughness, rainfalls differ, and so there is differential wearing of the land, producing the magnificent wild scenery of mountain regions, and mature scenery of wide valleys and the great wide fertile plains that bear so large a proportion of the earth's population. Wind levels and rounds off a region, producing wide regular contours; water carves gorges and valleys, producing cliffs and scarps and varied contours.

Waters run at a rate varying with the slope. Where the slope is great, the water runs and races, bearing along rock fragments and filing, even in hard rock, deep gorges,

so that in the mountain tract (170: 1) the river is deepening and gathering material. Having deepened approximately to a general slope from mountain to sea, it cannot deepen further; it widens (170: 2) out, swinging from side to side of the valleys, forming cliffs as it hits first one side and then another. This middle tract is the "valley tract," and the main works are widening and transporting material. In the "plain tract" (170: 3), the slope is little, the velocity is checked, and the stream cannot carry its load, which is deposited on flood plain and delta.

Thus the river, striving to reduce its area to a uniform level, cuts down here and builds up there; it is said to "strike grade" (170: 4). Let us sum up the cycle of erosion (170: 5). Uplift provides the block (a young plateau), young rivers flow in narrow steep-sided valleys with flat plains having indefinite water-sheds between.

PLATE 170.—THE CYCLE OF EROSION.
5, Uplift, wearing to Young Valleys and Young Plateau, Old Valleys and Old Plateau, Old Age, and finally a Peneplain.

The valleys widen, the sides wear back, the flat plains are reduced to ridges (residual ridges, 176: 6a), and the drainage is mature; each watershed easily defined (170: 5, 3). This area is now an "old" plateau or plain. In old age (4), the rivers flow sluggishly. At last, the river is just able to flow gently to the sea and the country is a peneplain (170: 5, 5), a river-cut plain in the last stage of senility. Changes may intervene, causing uplift, and set the whole cycle in operation again, so that the peneplain surface (170: 5, 5) might again be dissected (170: 5, 1); thus is formed a "dissected peneplain" (or peneplane).

B.—FLOOD PLAIN STUDIES.

People looking across a wide valley and noting a small stream in it often think that the rainfall must have been much greater at one time, for such a small stream could not make so wide a valley; but somewhat like the "hydraulic paradox," that a quantity of water no matter how small may be made to support a weight no matter how great, so within limits a stream, even if small, may, if given time enough, produce a wide valley.

The stream deepens, but not indefinitely. It reaches its "base level of corrosion," and cannot cut deeper except possibly as in such a small thing as "a pothole." The stream now is subject to all sorts of emergencies; soft rocks on one side are cut out rapidly, while hard rock resists; rocks or trees may fall and deflect the current to the other bank. It cuts into that and forms a bend (172: 1b). The stream, however, is no wider than before, it runs swiftly at the outside, and more slowly and may even eddy a little on the inside. Hence, while the stream picks up material on the outer side, it deposits on the inner, and so keeps about the same width. In fact, on account of the more rapid current, it may even be narrower when cutting at the base of a cliff than when flowing steadily in a straight course. In flood time, the waters cover the whole valley between the high banks, and a deposit of silt and mud is added. This plain built up of silt and fine material deposited by the river is called a flood plain (171: 1-4). As the river carries its working head backwards into the hills, it has less velocity in

the parts where it previously wore a valley. It cannot carry its load, which is constantly being deposited on the bed, at the sides and on the wide floor of the whole valley, the flood plain. Therefore it builds up where it had previously cut down, and hundreds of feet of loose, rich deposit may accumulate. This gives trouble later to the engineer who may require firm foundation for weirs, bridges, and such works, but provides the best of farming land.

Cliffs (171 : 3, a, b) are formed by the river itself, as it works to one side and undermines one side of the valley.

The flood plain (171 : 4a) is often highest just about the river. The water runs most swiftly in the center at the surface. It is hindered at the bottom and sides by friction, and deposits material there, thus raising the bed and banks. In flood-time, the waters rush on; when they

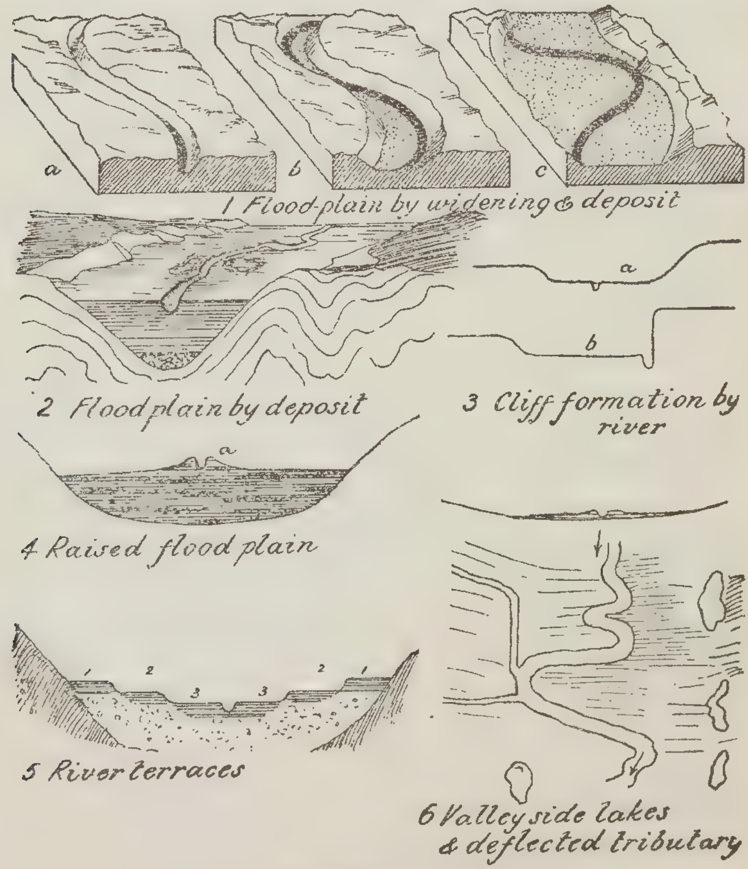


PLATE 171.—FLOOD PLAIN STUDIES.

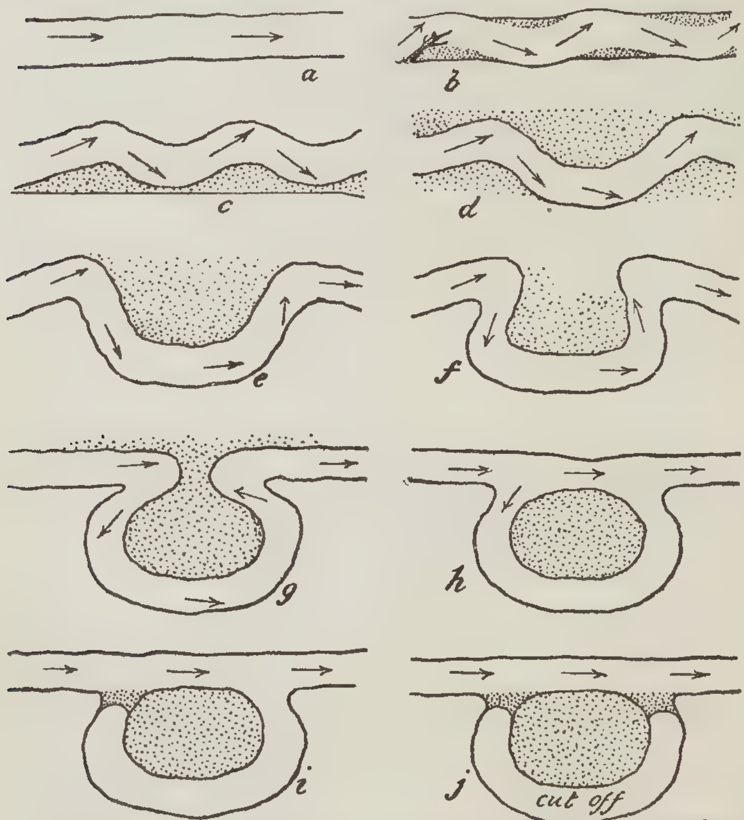
top the bank and spread out in the still waters at each side, or into the larger space available, the velocity is checked. Then silt is deposited along the edge of the river, producing the raised edge of the flood plain and the silt jetty (174: 6), projecting into lake or sea where there is not a current to carry the silt away. This raised edge is not due to uplift, as so many think. It is due to deposit along the line where the velocity is checked. The roads of the Mitchell and Snowy valleys often follow this natural levée, which is a source of danger to stock-owners. When floods are small, the cattle and sheep are driven towards the river, and feed there. If the small flood becomes a big one, the sheep and cattle cannot be removed, and serious loss results. Gippsland people explain that the river takes to the highest land, but not so. When the river changes its course, it takes to the lowest land, but soon builds that up above the general level of the flood plain. It is highly desirable on these extremely fertile areas to prevent the river from leaving its bed and spreading ruin and devastation through a rich, prosperous settlement. Hence no interference with vegetation and the natural protection of the banks should be tolerated. Cut off the scrub and trees, and the waters are free to remove the soft fine silt, and there is no telling where the damage will end. Many farms are now beds of stones (177: 7).

The raised river, though a source of danger, is often convenient for irrigation; siphons raise the water over the bank, and land is irrigated without the expense of pumping.

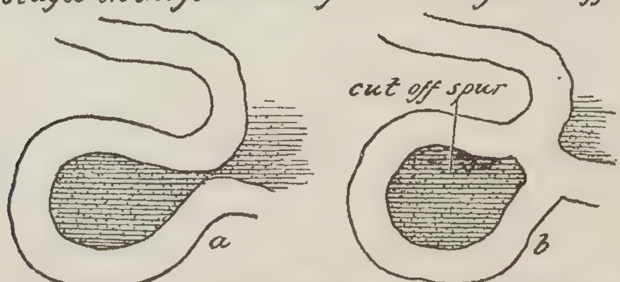
A river, having reached the mature, flood-plain stage (171: 5), may have its youth renewed by uplift or by the removal of a bar of rock, allowing a river to deepen. It then widens out, forming a fresh valley (2, 2), within its larger and older valley (1, 1). Soon a fresh flood-plain is formed at that level. Again the activity of the stream might be renewed, and a third flood-plain results.

Occasionally a river may show five or six of these flood plains at different levels. These are called river terraces (171: 5). A cliff might form on one side and remove all the terraces, leaving six showing on the other side. The highest is the oldest, and the lowest, the youngest. Some terraces are due to the swinging and grading of the river.

The raised edge of the flood-plain (raised flood-plain for short) influences the direction of flow of tributaries. A tributary (171:6) may flow direct to the edge of a flood-plain, highest near the river; the tributaries, being unable to flow uphill to reach the main stream, turn and flow parallel along the lowest part at the edge of



1 Ten stages in the formation of a Billabong or cutoff (lake)



2 Two stages in the formation of a cut-off spur (of land)

PLATE 172.—FORMATION OF MEANDER, CUT-OFF, AND CUT-OFF SPUR.

the valley. The Yazoo flows in this way for 150 miles before it can enter the Mississippi. The Goulburn flows west, parallel to the Murray River. The Murray, however, left its raised flood-plain and came to the south edge of the valley, so that the Goulburn now enters, and the Campaspe is able to enter the river directly, as illustrated by (171:6). Often, as in the chain of the Loddon and Murray lakes, water forms lakes along this low edge.

C.—MEANDERS, CUT-OFFS, AND CUT-OFF SPURS.

The formation of bends, meanders and cut-off sections of the river (172: 1, 2) can be studied on most flood-plains. Indeed a flood-plain is never level; it has many old curving hollows about the same width as the river.

The water of a straight-flowing river (172: 1a) may be deflected to one side. It cuts the outer part back, and is deflected to the other bank, cutting that back (172: 1 b). It is again deflected, so that the straight river may become highly tortuous. The deeper the cut, the more sharply the water is deflected, until a bend of more than half a circle (172: 1, f) is produced; still the stream cuts in, and at last flows round an island usually formed of silt (172: 1, h). Silt, dragging along the side, at last joins the island to the flood plain, and separates the bend of the river (172: 1, j) as a cut-off lake. Sometimes it happens that the river cuts through a part of the original high land, a spur from the plateau or ridge. This is then a cut-off spur of land. Hence there are two "cut-offs;" one more common, a cut-off bend of the river; the other, a cut-off spur of higher land (not flood-plain silt). The water cut-off is more common; the name cut-off is, therefore, used for the cut-off meander or billabong (aboriginal name), and the name cut-off spur for the piece of higher land separated by the river from the rest.

D.—RIVER STUDIES.

Rivers are active agents in altering the earth's surface. They struggle amongst themselves for territory. A river favored with softer rock, more slope, or more rainfall, can often capture territory and water from another with harder rock, less slope, or less water.

The steep working head of a river is the part that counts; it works backwards, so that it is sometimes said that waterfalls (176:4) travel up stream (173:2a). The one with steep slope, other things being equal, will beat the river with less slope. A straight watershed (173:3a, b) soon becomes complicated as the streams wear back into it.

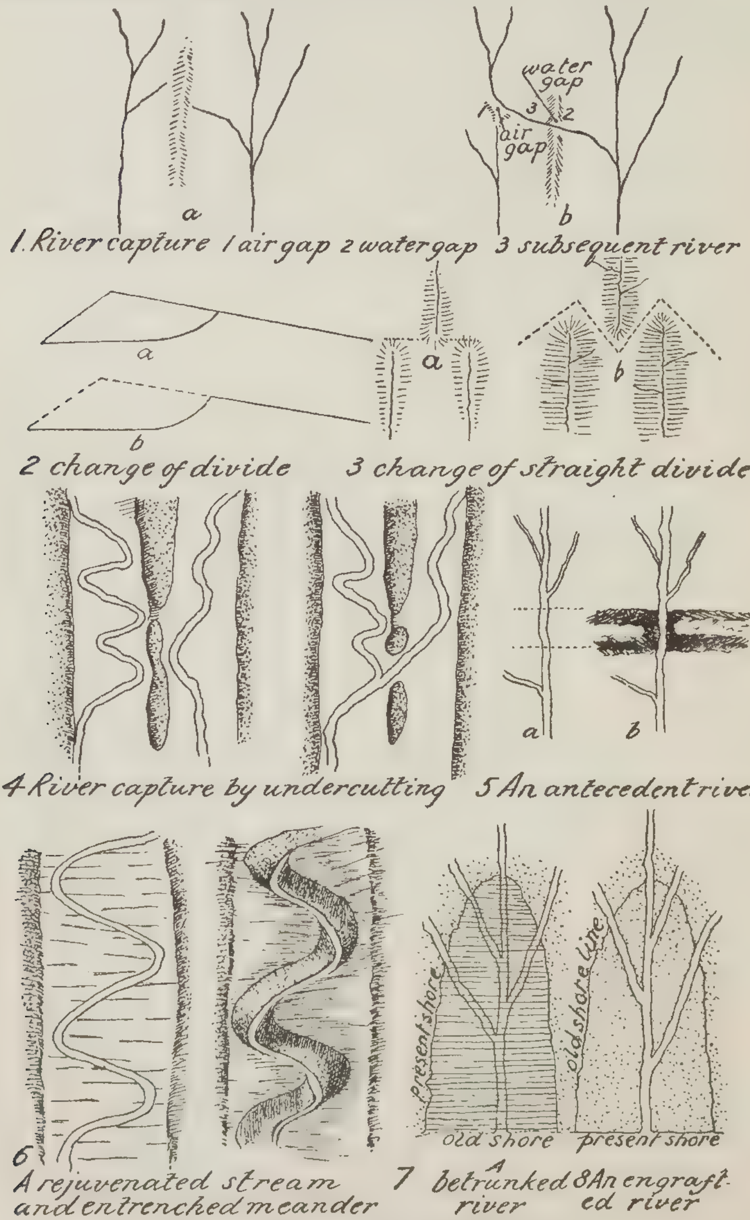


PLATE 173.—RIVER CHANGES.

A tributary at a lower level may cut back and cut across the head-waters of another stream (173: 1, b). These waters now flow along the capturing tributary into the other river. The gap in a ridge where the river cut through and now flows is a "water gap" (173: b). A gap in the ridge where the river no longer flows is called an "air gap" (173: 1, b1). The capturing part formed subsequent to the original disposition of the drainage is called a subsequent river (173: 1, b3).

One river, by swinging out at a bend (173: 4), may capture the head portion of another stream. The captured stream has been "beheaded." A dry valley is left.

Sometimes the country (173: 5), across the track of a river, rises slowly at less rate than the river cuts down. If it rose more quickly, the river would be broken into two parts. The country rising less quickly, the river maintains its course. The rising part becomes a "young,' gorge-like valley and a river rising at a height of possibly 1000 feet above sea-level flows through a mountain belt possibly 3000 feet in height; obviously the river was there first, or it could not have established its course. Rivers flowing through the Macdonnell Ranges in Central Australia are antecedent rivers (173: 5). The Yarra flowing through Christmas Hills is another.

The region of a mature river may be uplifted. The fall of the lower part of the river is increased, the stream has its youth renewed, it is rejuvenated. It deepens its bed often as a narrow trench, an entrenched or incised meander (173: 6) in the old flood-plain.

If the country, *e.g.*, the bed of Port Phillip Bay, sinks, the many tributaries become independent rivers, and the main river is a "betrunked river" (173: 7).

On the other hand, if a region rises, as the mouth of the Murray, including much of Western Victoria as far up the river as Swan Hill, rivers that formerly entered the sea separately are now engrafted on to one trunk, forming an "engrafted" river system (173: 8). The same effect has been produced in Gippsland, where the sand-drift of the Ninety-mile Beach has forced some streams to join and reach the sea by one mouth.

CHAPTER XXX.

LAKE STUDIES.

Lakes and rivers are closely related. A lake is an interesting feature. No old lake (geologically) is possible. Either it will be filled or emptied before it can be called old. A lake is possible on a "young plain" (170: 5, 1), one is not possible on an old plain (170: 5, 3), where each

PLATE 174.—RIVERS AND LAKES.

watershed is distinct. Rivers are the natural enemies of lakes, though we have noted two ways in which rivers form lakes; by causing accumulations of water (174:3) in depressions along the edge of the flood-plain (171:6), and by forming cut-off lakes (172:1; 174:1).

An active tributary, by depositing silt and stones across a sluggish river, might cause a lake (174:4).

Waterholes, so common along the course of streams in Australia, are pot-holes on a large scale (174:2). The moving waters, stirring up sand grains and stones, wear out soft, earthy material, or even hard materials.

However, it is a matter of time only before material carried down by muddy waters fills the lake (174:5, 6).

Plate 175.—SOME LAKE STUDIES

Meanwhile, the waters flowing from the lake wear the bed deeper and deeper, until at last the lip of the lake is cut down (174: 7a, b), and the waters escape, leaving a dry "drained-lake" bed of very rich soil, suitable for agriculture. The wearing, however, is slow, for the water filtered in the lake has no filing material. The Rhone, issuing from Lake Geneva, flows over a bed of soft, clayey limestone. It is said that little of this has been worn away since the time of the Romans. Moving water, plus sand, wears anything, but pure water wears slowly.

Earth movements also assist in forming lakes. During wrinkling and warping, an area may warp down, forming a basin (175: 1) like Lake Omeo. In rift valleys (Dead Sea, Red Sea, and Spencer Gulf and Lake Torrens) an area has been faulted down.

A coast may sink, and the river valleys are drowned (174: 8, b; 173: 7), forming lakes, harbors, and inlets. The sand drift may close the mouth, and form a lake.

Many rock basins are said to be due to the wearing of glaciers.

Some of the lakes of Western Victoria are due to the removal in solution of underlying beds of limestone (175: 4), leaving a shallow basin, in which water collects.

A volcano, having ejected much material from below, may subside wholly or in part, thus leaving a hollow (a caldera), in which water collects; or a great explosion may blow out the greater part of the mountain.

Subsequent volcanic action may build up volcanic cones on the floor. These may project as islands. Crater Lake (Mt. Mazama) is a famous American volcanic lake. Tower Hill, near Warrnambool, Victoria, is almost equally famous.

Wind (175: 7) and ocean (175: 5) also build barriers and cause lakes.

As already mentioned, no lake is old, river deposits will fill them. So also will plants floating and rooted in time fill them with plant remains. At the Melbourne Zoological Gardens, a circular well, having bricked bottom and sides, and fifteen feet deep, was filled in a few years by dust and the remains of water-plants. Beds of plant remains take a large part in the formation of rich "bottom soils." Similar beds have formed peat, lignite, and coal.

CHAPTER XXXI.

SOME FIELD FEATURES.

At the foot of a cliff is a slope of the fragmentary material; this is a *talus* (176: 1); if the matter is coarse, it is often called a *scree*.

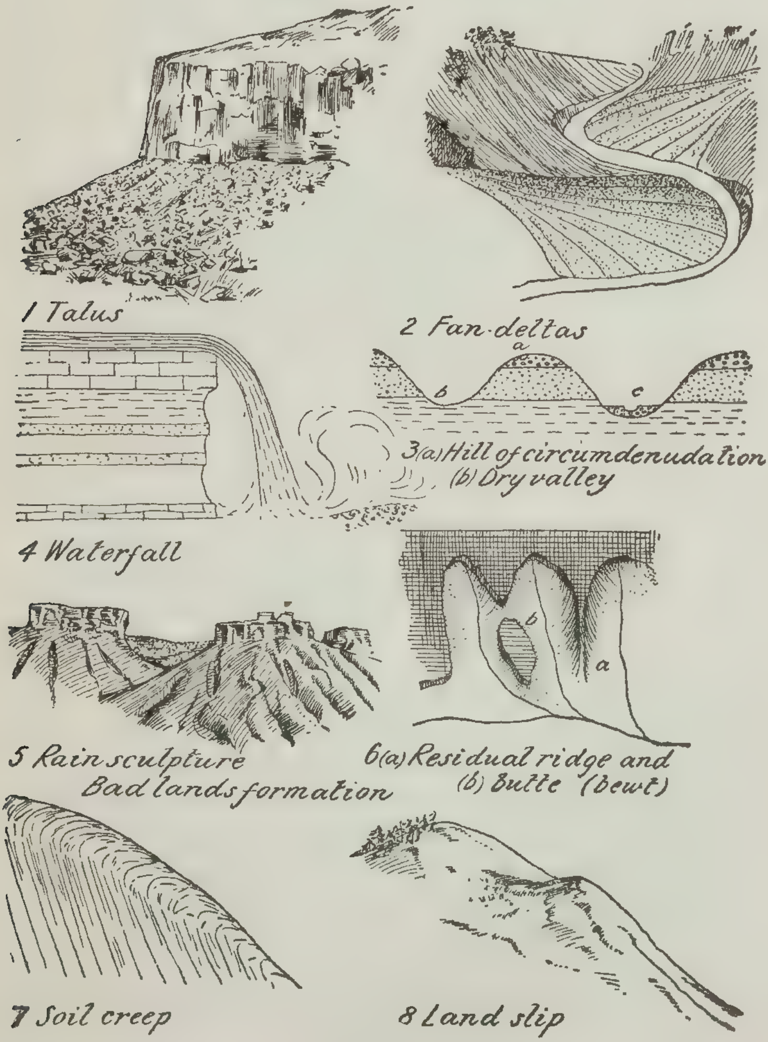


PLATE 176.—SOME FIELD FEATURES.

It has already been shown (plate 171) that rivers strike grade and produce areas of deposit. The material is not carried far (176:2; 171:4). If the slope is steep at the junction of an area of less steep slope, the velocity is checked and a cone of material is deposited. The stream runs out to one side and then is diverted to another. When that is built up, the stream is again diverted, until a "fan delta" deposited on land at the foot of a steep slope is formed. Alluvial fans and delta cones are other names. Series of such fans along the foot of a mountain region form great plains, such as the Canterbury Plains of New Zealand. Fan deltas in Swiss lakes and Norwegian fiords provide almost the only sites suitable for towns. Ordinary deltas are called river deltas or simply deltas.

Waterfalls (176:4) are also temporary features. In old widened valleys, waterfalls have been worn away and reduced to the general level. A hard band or ledge gives the water increased velocity as it leaps into the hollow. It stirs up stones and wears out a basin. Some water trickling down the face trickles out soft beds, and harder pieces break off. The splashing of waters, too, helps to wear back the head, which gradually works up stream.

A hill of circumdenudation may be a "cut-off spur," though all hills isolated from their original rock-beds by denudation have not been formed as cut-off spurs. Sometimes a river (172:2) has deserted its old valley (176:3), which now becomes a dry valley, and the hill between the two valleys is usually a hill of circumdenudation.

Often very soft rock lies under a hard crust. The crust protects the underlying rock from rapid erosion. The crust might be due to grass roots (177:1), or a cemented layer (176:5), like the desert sandstone of Central Australia. The cement may be derived from ascending water evaporated at or near the surface, depositing a layer of limestone, ironstone, or silica. The crust layer may be due to compacting, as by traffic on a road, or due to sun baking forming a kind of natural sun-dried brick. When the crust is broken, the drainage water gets to the soft rocks, clay mixed with sand below. These trickle out often as semi-liquid mud, The whole country in wet weather seems to melt. Bad lands—"rain sculpturing"—(176:5; 170:4) form, and the country may be impassable.

The Bad Lands of South Dakota (U.S.A.) had been cultivated before the civil war, and then deserted, owing to the scarcity of labor. When the owners returned to their farms, they found the country a series of chasms, narrow ridges and gorges, the drainage water flowing 200 feet below. Over 1000 square miles of country was ruined, and lies useless and unusable owing to the uncontrolled run-off of the water from the land.

The ridges left in the wearing away of a plateau or plain (170: 5, 3; 176: 6a) are usually called "residual ridges," the residue of the plateau. Harder parts of the original surface may be isolated, as the wearing proceeds. Such a piece is called a "butte," a French word pronounced somewhat like *bewt*. Larger flat masses of similar origin are called *mesas* in America.

Land slips (176: 8; 164: 8) occur in steep-sided valleys or about cliffs, or railway or canal embankments.

When inclined strata are met with near a hollow or valley, there is a tendency for the whole surface (176: 7) to settle slowly and bodily into the hollow. This is usually referred to as "soil creep." A fence is often carried out of the perpendicular by such surface creeping. In road cuttings, this may be mistaken for rock-folding.

CHAPTER XXXII.

SOIL EROSION.

To prevent the entire removal of the soil, some hill-sides are terraced, thus causing deposit (177: 2).

The importance of vegetation (177: 1-7) in saving soil cannot be over-estimated. Close inspection of a wash-out, a small canyon (177: 4) being cut out on the edge of a valley, will show that, though much loose rock material is being removed, yet little or none is reaching a pool some yards away. The grass acts as a filter, and from the end of the fan delta, built up of material removed, no sand is carried, even the few yards through the grass.

Trees and scrub on hill-sides are important. Nature has established a permanent balance, some trees and so much grass and herbage to a certain area. The land is

open and park-like. The ringing of the trees upsets the whole balance. Sometimes dense scrubs and numerous seedlings appear to make good the damage. Much land in Victoria, previously park-like, is now clothed with dense scrub. When the trees died, rain descending on the hill-

Plate 177.—VEGETATION AND WATER FLOW.

side and finding no sponge of twigs, leaves, and bark, the water ran quickly down the hill, carrying the soil with it; soon bare rocks were exposed on the slope which lost its grazing value. The rocks loose on the hillsides (177: 3a, b) were dislodged and rolled to the alluvial flat at its foot. The flat, littered with rock fragments, also lost much of its value.

The removal of a forest is fraught with great danger. The lumber industry in certain districts of America is said to have "committed suicide" by its faulty treatment of the forests. At the beginning, the forest was valuable; the rivers were steady, deep, and permanent; springs abounded; crystal-clear water trickled to the rivers, and water-power was available for working sawmills; timber was readily conveyed by water to the coast; alluvial flats were abundantly irrigated; deep harbors at the river's mouth provided facilities for towns and shipping: prosperity ruled. But the forest was cut down in a face. The snow melted two months earlier than it did in forest country, where it melted slowly and steadily, feeding springs and streams. Each rain produced a raging torrent; leaves, twigs, soil, clay, and sand were swept into the rivers and filled the reservoirs. Springs went dry, water power was not available, for the mad, rushing flood after each rain was unsuitable for water-power. The rivers became sand-beds, and the sand marched on until it choked the harbors. Each rain produced a flood, and there was a drought until the next rain. People then said that the climate had changed, the rainfall was much less; but not so. The run-off of the water was not regulated, and that made the difference. Forests do not increase rainfall to any appreciable extent; they regulate the flow-off of the water. Good forests on the watersheds of a country are a great insurance against floods. The water slowly trickles down, and takes weeks instead of hours to reach the bottom of the valley.

Vegetation protects the banks of rivers, and no man should be allowed to clear those banks or to destroy vegetation on them. The Avon River, in Gippsland, with little vegetation on its banks, now has a bed of shingle (*e.g.*, 177: 7) many times the width of the stream. The river is a menace to all who own property near it.

CHAPTER XXXIII.

SPRINGS AND WELLS.

Springs and wells are of importance. Water percolates down through limestones and sands, but does not pass through clay. It travels along underground, and oozes out where the clay is exposed on the hillside (178: 1, 2).

In diagram 178: 3, c, the creek is a winter one at best, while at *f* is a permanent stream fed by the underground waters accumulated on the impervious clays; *d* is a permanent well, while *a* soon goes dry.

Another form of spring, a fault spring (178: 5), is shown in figure 5. A fault has lowered the right-hand block with water-bearing strata. This rises along the line of junction, the fault line, and flows out at the surface.

A model spring (178: 8) can be made with pipes. The water soaks down through soil to sand and runs from the pipe at the top of the clay.

A flowing well is explained by diagram (178: 4). Water is imprisoned in a layer with clay above and below. The water from the well should rise to the height of the imprisoned water. Australia is a land of much valuable artesian water, and many flowing wells. The usual explanation is that the tropical rains of Queensland flow down these pervious strata underground under Central Australia. Bores often more than half a mile deep tap this water, which flows over at the surface, proving of inestimable value. Professor Gregory, claiming that the water is not due to rain, has sounded a warning against wasting these precious stores. Flowing wells were called artesian wells from Artois, in France, The water imprisoned in a basin, with clay above and below it, rose to its own level in a well situated in the basin.

Some springs run and then stop; these are intermittent springs (178: 6). The overflow acts as a siphon (178: 6) It fills to the level of the bent overflow and then empties. It cannot run until it again overflows in the bent outlet.

An infallible sign, in the opinion of old bushmen, that a drought will soon end is that the "springs begin to run" in dry weather. Sure enough, they do begin to run. A

probable explanation is that the drought has dried up some of the underground water, and so dried the upper impervious layer that it has cracked. The imprisoned water emerges through the cracks and the spring "runs."

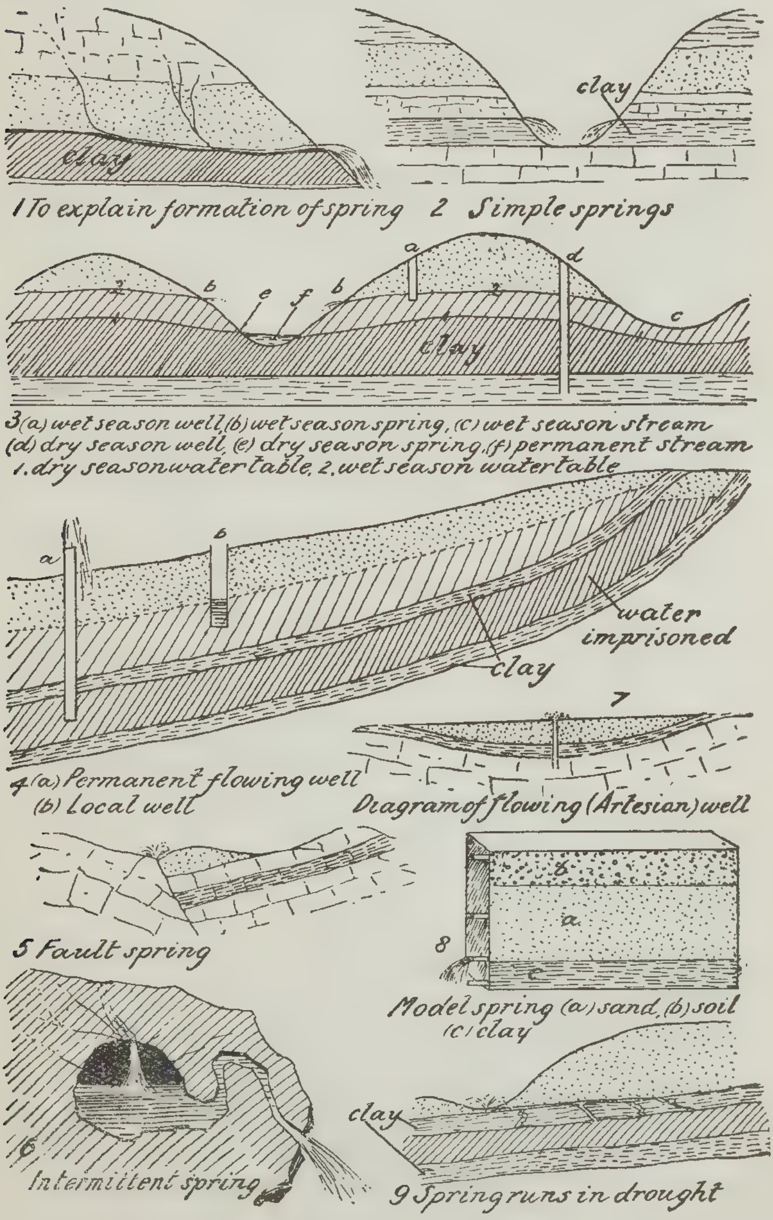


PLATE 178.—SPRINGS AND WELLS.

CHAPTER XXIV.

THE SOIL.

The geologist often regards the soil, the altered surface layer, as a nuisance. He searches for places devoid of soil, where he can see what is beneath. Still the wealth of the country and happiness of the people depend on the soil.

Soil can be formed directly from the decay of the underlying rock; it is then a sedentary soil (179:1; 160:8; 162:9), formed where found, or it may be a transported soil (179:2; 177:6), formed elsewhere, and transported to its present position.

A convenient way to determine the composition of soil is to conduct a mechanical analysis (179:3a-g).

A weighed sample of soil is taken. It is air-dried (*a*) and weighed. Next it is steam-dried (*b*) over a vessel of boiling water and weighed. The total loss equals the amount of water present. It is now burnt (*c*), while well stirred, until no smoke arises. Black soils may now become grey. The black is carbonaceous matter (humus) derived mostly from animal and plant remains. Some volcanic soil may have black oxide of iron present. The soil is now sieved (*d*), separating the larger fragments—coarse sand and gravel. It is then boiled (*e*), and allowed to stand until settled; the water is decanted (*f*) off, separating the water-soluble and the insoluble parts.

A fine sieve (*g*) now separates the fine sand. Having weighed the material carefully at each stage, one may now determine the percentage of water, humus, clay, fine sand, coarse sand, and stones present in the sample.

Gardeners make soil by mixing certain ingredients. Nature does that also. The earthworm (179:5) can be shown to be important in soil-making. In a vessel of damp, white sand, six earthworms and six dead leaves are placed; soon the burrows are lined with black soil.

It is said that, in a forest, the whole of the soil is turned by falling trees (179:6) once in each 400 years.

Many experiments with soils and manures are suggested in such textbooks on agriculture, as McLennan and Refshauge's "An Australian Textbook of Agriculture," so that space cannot be given here, though certain points are illus-

trated. Some growth experiments (180: 1), showing the importance of soil, subsoil, manure, and humus should be performed with pot-plants.

Drainage rates (180: 2) of different soil materials should be illustrated; sand, clay, and soil are usually compared. Then the water-holding capacity (180: 3), the amount that does not drain through, can be determined.

PLATE 179.—SOME SOIL STUDIES.

A supply of water stored in the subsoil is all important in dry weather; so some capillarity (180: 4) experiments must be performed, and many observations made.

The effect of lime (180: 5) on clayey soil should be illustrated. The best treatment of clay to secure proper drainage and adequate growth is important (180: 6).

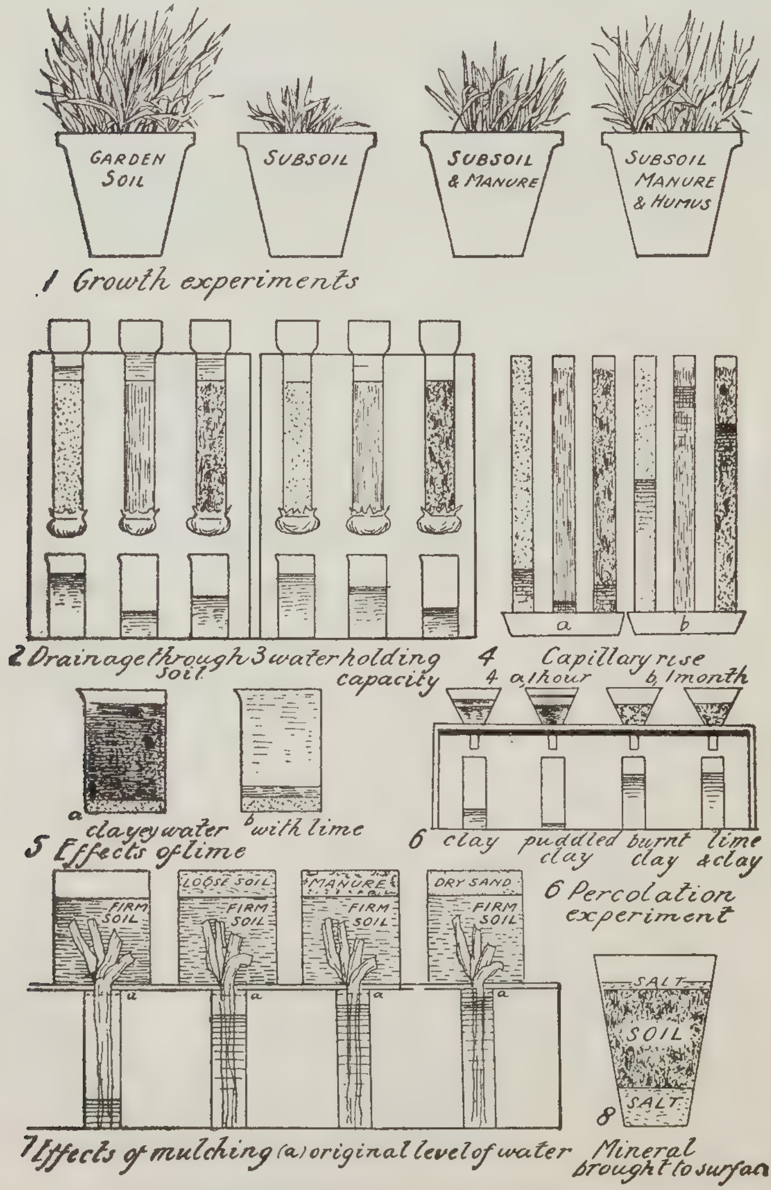


PLATE 180.—SOME SOIL EXPERIMENTS.

The effects of different mulchings (180:7) will provide good observation work.

The danger of irrigation without drainage (180:8) can also be illustrated by experiment. Harmful salts may be brought from a considerable depth to the surface layers.

CHAPTER XXXV.

WATER STUDIES.

Water has been shown to be essential to life, and has been studied in many phases, especially in plant life. Water on the physical side provides many interesting studies.

A.—CIRCULATION OF WATER.

Experiments.—(1) Boil some water until none is left.

(2) Boil water in a Florence flask (181:3) fitted with rubber cork and long delivery tube; cool this tube, and collect the water. You obtain the water with which you started; it has been distilled—evaporated and condensed.

(3) Boil water in a Florence flask (181:2) fitted with cork and glass tube. See the *cloud* of "water-dust" near the tube; steam is invisible.

(4) Dry wet cloths. Where is the moisture?

(5) Bring a vessel of iced water into the room; water forms on the outside of it (183:10).

Establish the circulation of water—to vapor, to water. The same water may be used over and over again. "Over and over again" is a great law of nature.

Water evaporated over the ocean (181:1) is carried inland and falls mostly on the mountains as rain or snow. It flows back to the ocean, thus completing the circulation.

Filtering separates the mud or other solids from water. A filter paper is folded and placed in a funnel. The liquid to be filtered is poured down a rod.

A filter for household use should permit of frequent cleaning. One bad lot of water passed through a permanent filter would make it dangerous.

B.—THE BOILING OF WATER.

Boil water in a flask (182:4). Boiling is bubbling. The water is boiling when bubbles of steam reach the surface.

The "singing" of the kettle is due to the bursting of bubbles rising from the hotter lower part, but not having pressure enough to reach the surface. Hear the water sing. Listen! Remove the lamp; replace it; listen again.

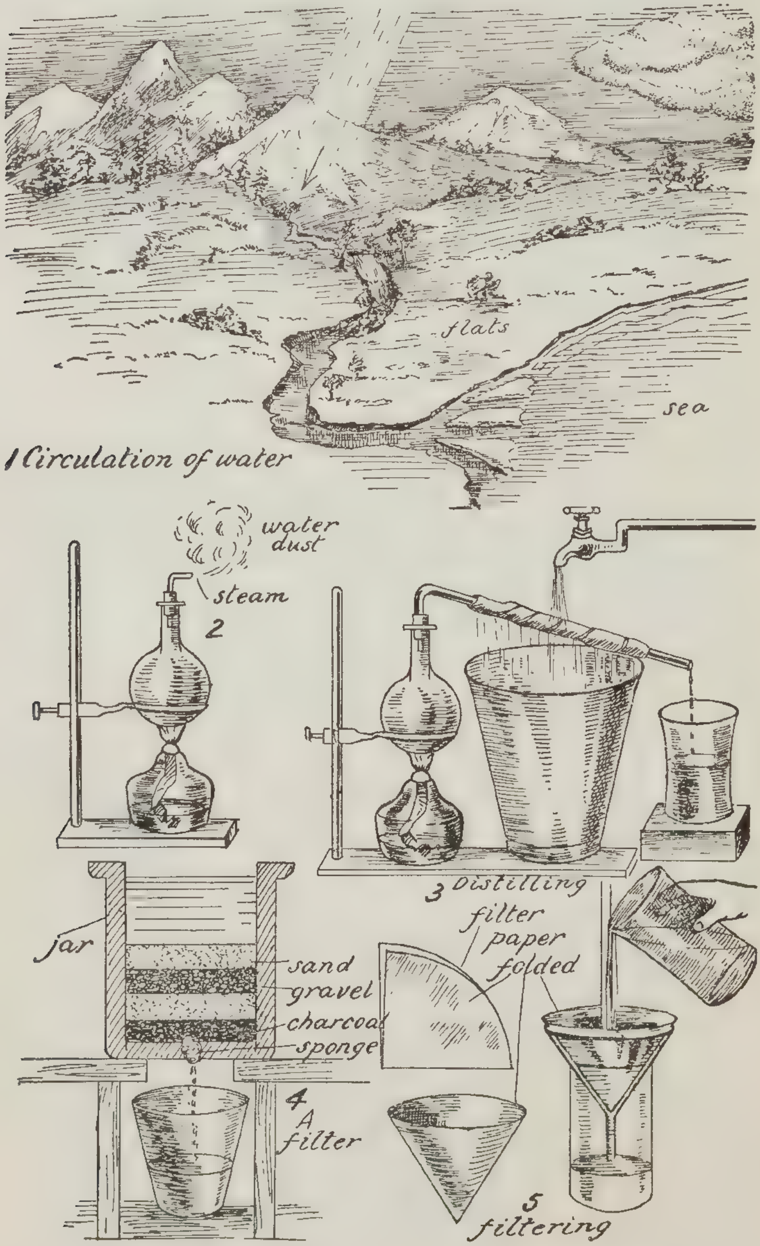


PLATE 181.—THE CIRCULATION OF WATER

Remove the spirit lamp (182: 5), and quickly cork the flask, excluding the air. Now invert the flask and pass the neck of the flask through a retort stand into cold water.

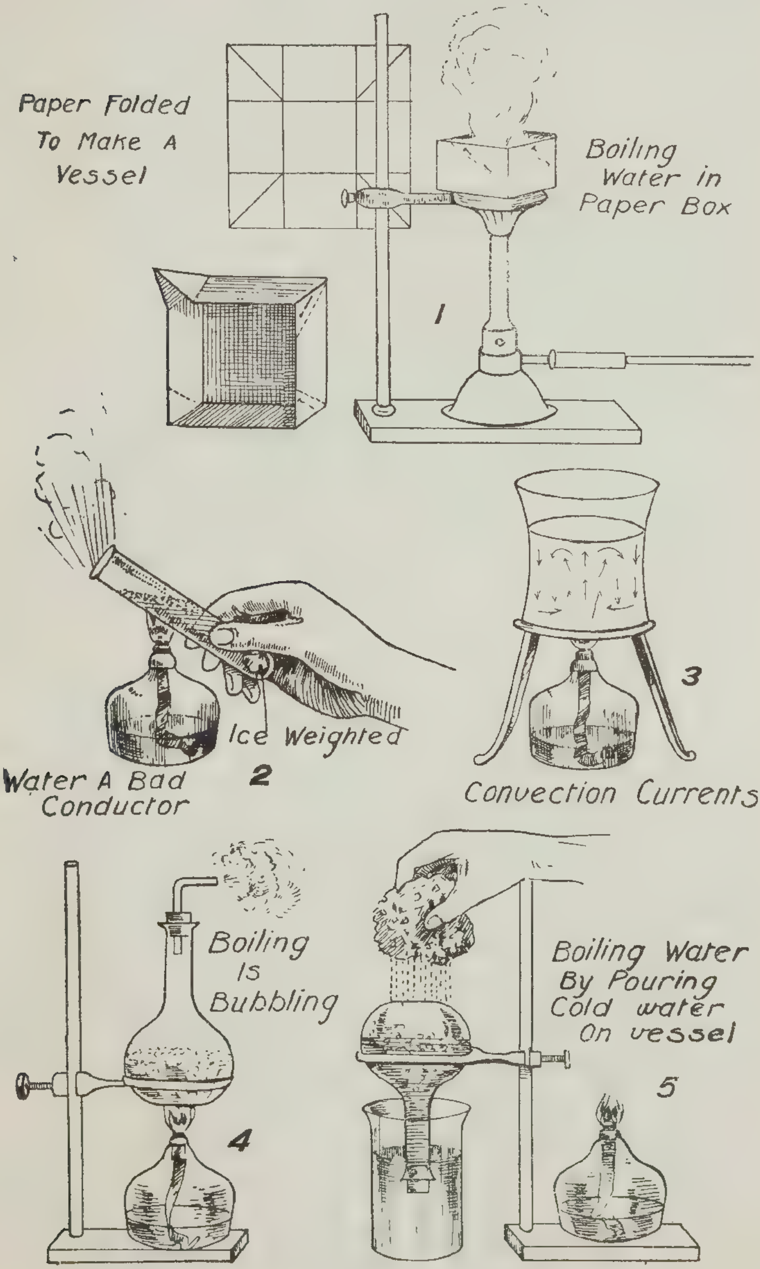


PLATE 182.—THE BOILING OF WATER.

Pour cold water over the flask; the water boils *violently*, and again stops; repeat this; the water boils again, and again ceases. Shake the flask; the water rattles like shot. There is no cushion of air between water and glass.

The air was expelled by steam. On corking, the steam filled the flask above the water. The cold water condensed the steam to water, reducing the pressure. The water again boiled, giving off more steam, until pressure again prevented bubbling. If ice-water is now applied, a further boiling may result. Remove the stopper, noting the explosive inrush of air; pour some water, "boiling' a few seconds previously, over your finger.

To boil water by pouring cold water over it was wonderful; to find "boiling water" so cold is surprising.

Boiling point, therefore, varies with the pressure. Professor Gregory's native carriers on a high mountain in East Africa could not cook their beans. They thought evil spirits were interfering with the pot. An egg or a pudding cannot be boiled in an open saucepan on Mont Blanc. Professor Gregory, in East Africa, calculated his height above sea level by taking the temperature of water boiling in an open vessel.

Boil water in paper (182:1). Take a piece of writing paper (foolscap), about 4½ inches square; fold down 1¼ inches on each side; "stand up" the sides, placing the lines of the folds at each corner together, pin the overlap to the box. Pour water in gently. Place it over a spirit lamp. Children are astonished when the paper does not burn. It cannot burn until all the water has evaporated; while water is present, the temperature cannot rise above boiling point (212° F.); below the burning point of paper.

When the water boils, pour it out, and pass the paper round for inspection—it is uninjured. Now place the box of water on a good fire. It cannot burn except above the water-line. Remove it for inspection.

Hold a test tube of water by the bottom (182:2) over a spirit lamp. The water boiling on top, remains cold below. Water boils above, while ice, weighted by wire, remains below. Heat is communicated in liquids mostly by convection (182:3), Convection acts from the source of heat upwards. Liquids are bad conductors of heat.

C.—FORMS OF WATER.

Experiments.—(1) Boil water in a flask fitted with cork and glass tube (181 : 2). See the cloud of water-dust (minute drops) near the outlet. Of what is the cloud made? Whence comes it? Whither goes it?

Refer to your breath on a frosty morning. Of what is the cloud made? Warm air holds more invisible water-vapor than cold air; the cloud is not seen on a warm day.

See the cloud from a railway engine disappear at the edges into thin air. When the cloud spreads into a wider expanse of air, the watery vapor becomes gaseous, in-

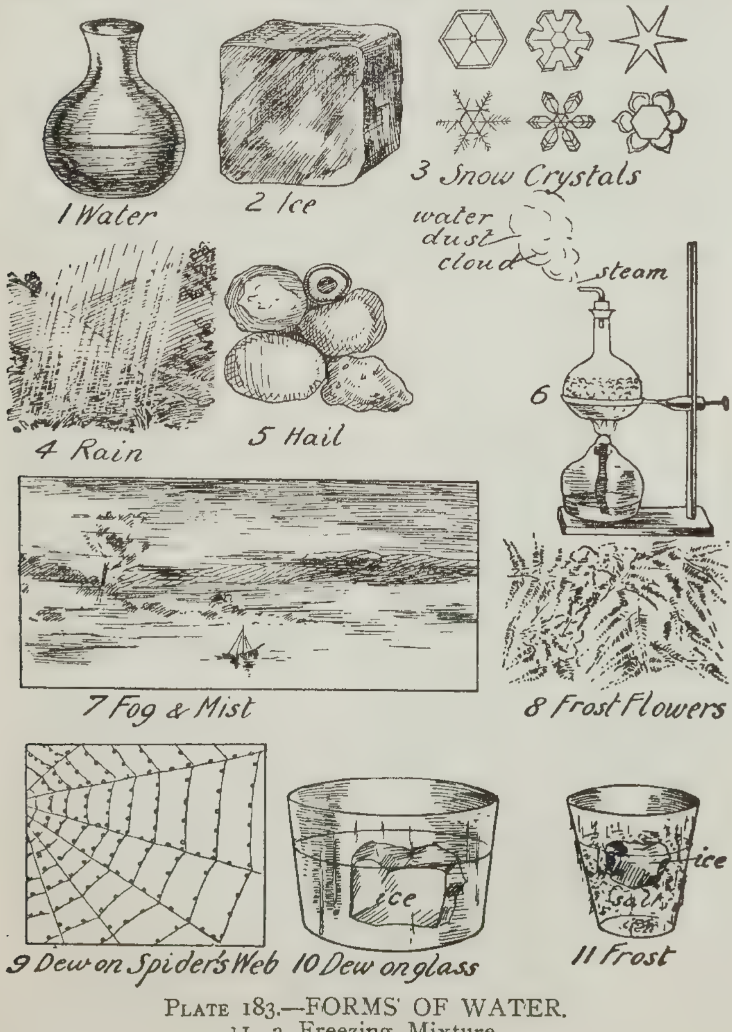


PLATE 183.—FORMS OF WATER.
11, a Freezing Mixture.

visible. There was too much water for a limited amount of air to hold in the invisible form. On a dry day, the cloud soon disappears; on a moist day it lasts longer.

Air at any temperature can hold only a certain amount of water in the invisible form. The temperature at which the air can just hold its moisture, or below which condensation of moisture would begin, is the dew-point.

If the air cools to the dew-point, the invisible water-vapor of the air becomes water-dust, or is deposited as dew on objects cooling the air.

If there is much moisture, dew will form at a comparatively high temperature. If there is little moisture, deposit goes on about the freezing point or below. The water now being deposited is frozen into beautiful crystals (183: 3), which contain air and refract light, so that they appear white. These water-crystals are "hoar-frost." Though the crystals are three or six sided, and the angle is constant, there is an infinite variety of these beautiful forms. On the window after a frosty night, "ice-flowers" in plant-like forms, may be seen. The crystallizing water has taken plant-like forms that remind one of dendrites (166: 13). In this winterless land, the opportunities are not good for the study of ice, snow, and frost.

See dew appear and disappear on vessels of cold water (183: 10). See frost (183: 11) form on a vessel containing powdered ice and salt, a freezing mixture used by Fahrenheit to get the zero (0 deg. F.) for his thermometer.

Clouds are masses of "water-dust"—water finely divided. The surface of the droplet is great in proportion to the bulk. The droplets fall slowly. Dust floats on water; mercury, though 13½ times heavier than water, if squeezed through a handkerchief, floats on water. Gold-leaf blows away, though gold is nineteen times heavier than water.

The droplets of a cloud or fog are so minute that they do not fall; a current of air may drift them upwards, as it does a thistledown or a feather.

In a mist, the droplets have become bigger by joining, or by having more water deposited round them. If they become still bigger, they fall as rain.

Hail (183: 5) often does much damage. While snow is more common in arctic regions and in winter, hail is more

common in tropical regions and in summer. It seems possible that electricity has much to do with its formation. Possibly the drops are attracted from cloud to cloud, coalescing and growing each time, and becoming larger in size. Some show a banded structure in cross section, others may be almost ragged lumps of ice.

D.—CLOUDS.

The wonderful beauty, glory, and infinite variety of shape, color, and change of nature's great picture-book—the sky and clouds—should be enjoyed.

In nature, there are "no hard and fast lines." The four chief kinds of clouds merge, giving endless variety.

If an object is between us and the light, it presents the shaded side to us. A cloud between us and the sun reflecting no light appears black. At the edges, light is

PLATE 184.—CLOUDS.

reflected to us, and the cloud has a "silver lining." A cloud away from the sun reflects light and appears bright.

Cooling is the cause of the change from invisible watery vapor to the visible cloud. If a gas expands, it cools. An upward current of air is an expanding, cooling current. The great fleecy and woolly masses, cumulus clouds, are often formed by the cooling of ascending currents over a heated region. A wind blowing against a mountain is forced upward; a cloud appears, and remains over the hill. The air past the range is descending, is being compressed and warmed, or is being warmed by heat from the earth. The "water-dust" becomes invisible water-vapor.

Light feather clouds (cirrus), blown out into "mare's tails," indicate wind, or they may form a "mackerel" sky. Usually these clouds float high, and are formed of ice crystals. Stratus (layer) clouds, fine-weather clouds, are often seen about sunset in long layers. The dark rain clouds are named nimbus (184).

CHAPTER XXXVI.

THE SURFACE OF WATER.

A.—PHYSICAL.

Each child has a glass vessel of clear rain-water. Hold the bottle on the fingers with the water surface at eye level. Look at it. Hold it as high as possible. Bottles down! What did you see? "The top looked dark." Hold bottles just above the eye. "Is that right?" "Yes." "Anything else?" The top is bright. Hold bottles high. "Is that right?" "Yes." The color brightens according to the angle, and surroundings.

"Who can say anything about it?" "It looks like ice." Bottles high. "Is that right?" "Yes." "What else?" "Like glass, tin, looking-glass."

We shall see. Let all see a clear vessel held high alongside a small looking-glass. All see the resemblance. Would this looking-glass act as a mirror if held horizontally?

We shall try. Hold the mirror high, about a foot before you. I see a girl, white dress, black hair. Stand, that girl. Could you see me? "Yes." Let all see. "Can

I use the water-surface as a mirror?" We shall try. Place a tumbler of clear water on the mantelpiece; children on opposite sides see one another. Refer to the former use of wells and shady pools as mirrors.

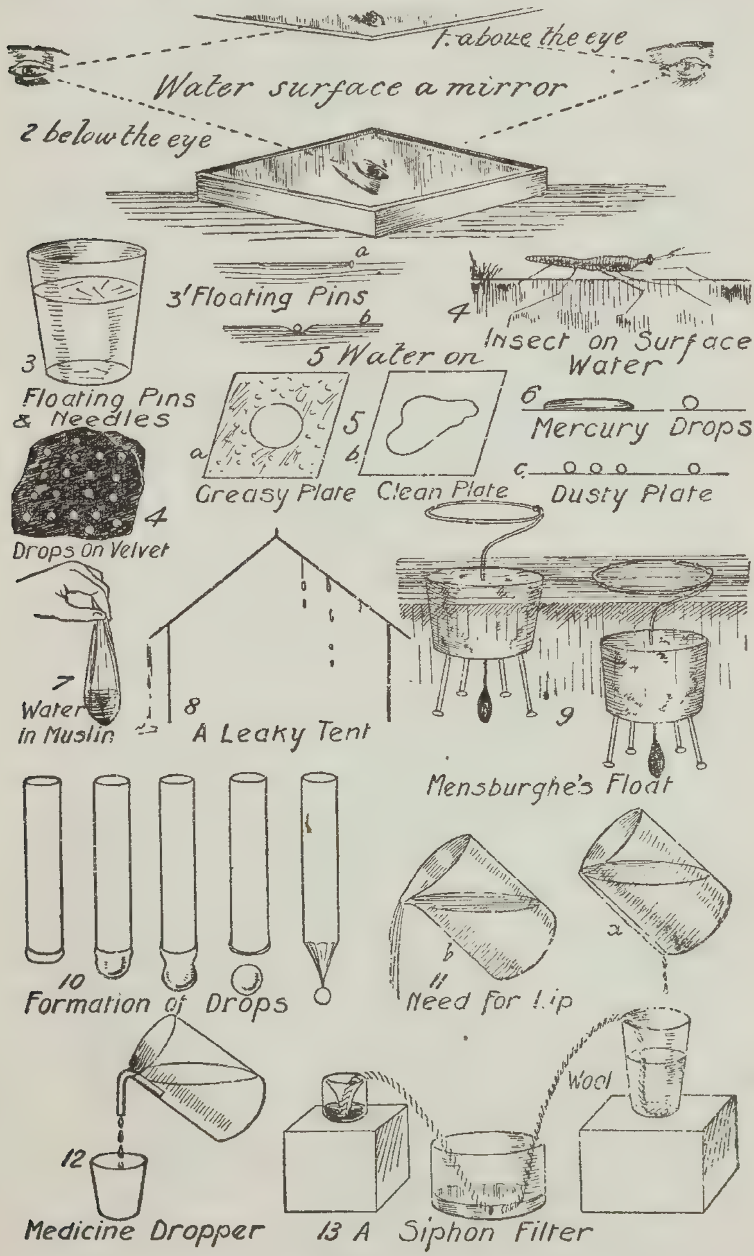


PLATE 185.—THE SURFACE OF WATER. I.

If we can use the water surface as a looking-glass when looking up (185 : 1, 2), can we so use it when looking down? "Yes." See the window reflected in the bright surface.

Is the surface strong enough for boys and girls to walk on. "No, not nearly." Is it strong enough for anything to walk on? "Yes; some animals run on it" (185 : 4).

The water-surface is a wonderful thing. The clearer and purer the water, the stronger it is. It is sometimes called "the skin of the water," but it is not a skin, for you cannot cut it off. It is excessively thin; and has different properties from the rest.

Float a fine needle (185 : 3, 3^1) on water. Is it heavier or lighter than water? "Lighter" is the usual answer. When touched, it sinks. Is it heavier or lighter? "Heavier." It cannot be both; take another. Is this needle heavier or lighter than water? "Lighter." Let it drop on the water; it sinks. The children agree that needles are heavier than water. Float another. What holds it up? See that the surface is bent down.

Thin things (those with a comparatively large surface) float if gently placed on the water; a fine pin floats. Mercury squeezed through calico in fine drops floats. The surface also supports a fine wire ring. Will it keep anything down? A toy, Mensburghe's float, supplies a striking answer. Bend fine wire into a two-inch circle, loop the end (185 : 9), and mount it over a cork. Weight the cork until it floats with its surface just above the water. If too much weighted, it sinks. Press the cork down until the ring is below the surface. Let it go. The ring should catch the surface. If it comes up, put in another pin; it is held below. Tilt the vessel and let go. The cork rises.

What holds the cork down? Lift one edge of the ring through the film; it soon frees itself. Pushing the cork to the bottom, let it go; it rushes up against the surface. Often the surface stretches with it and pulls it back.

Next, refer to the lip on jugs and tea-pots (185: 11 a, b), to prevent the surface from clinging to the side of the vessel. Make a dropper (185 : 12) of stout write. Let

children dip a finger into water. What shape is the drop? "Round, like a ball" (185: 10). What made it round? "The air pressing in on all sides" is the usual answer. But drops are round in a vacuum.

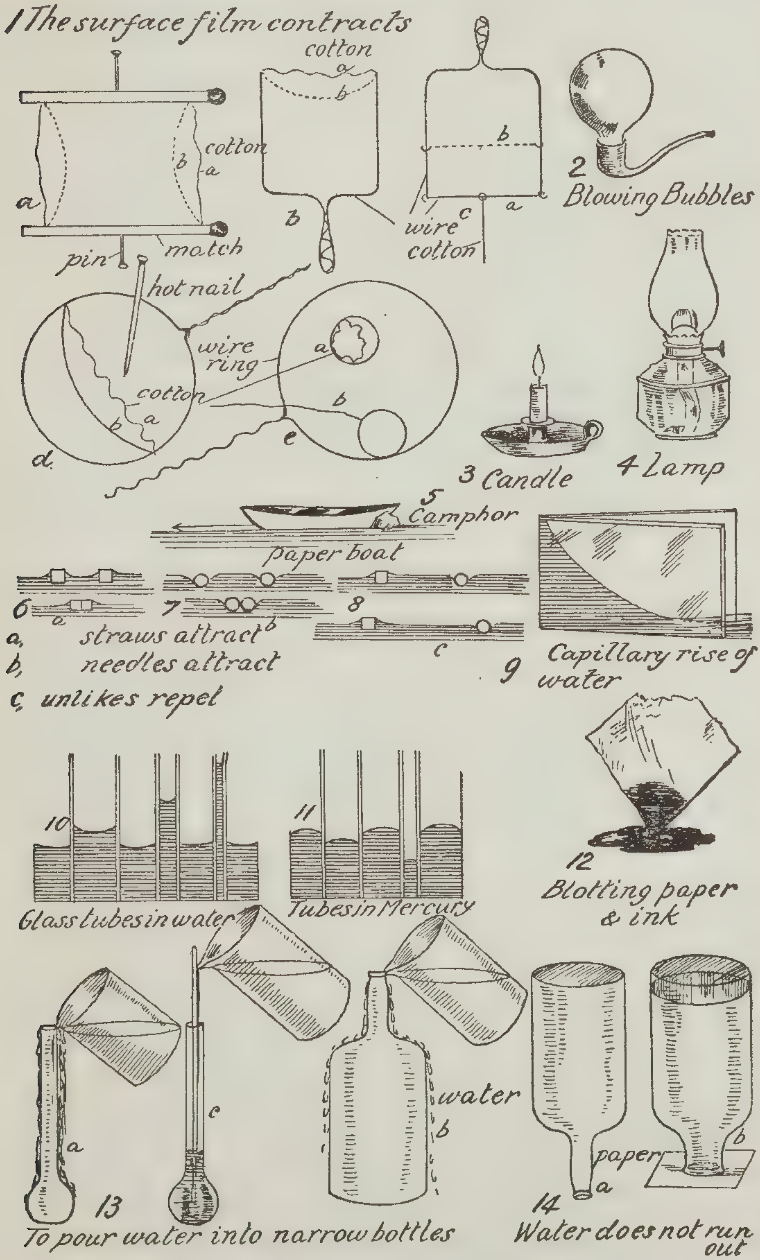


PLATE 186.—THE SURFACE OF WATER. II.

What holds the drop to the finger? Why does it not fall at once? It seems to have a thin bag round it. Gently jerk it out from the finger. The drop tends to fly off, and the film pulls it back; it grows, breaks, and falls.

Drops from the same point are the same size. You can jerk smaller ones off. Dip a finger, lead pencil, point of slate pencil, point of pen-nib, into water, and see the different-sized drops. On a sharp point, the drop is almost spherical before falling. At once, the surface contracts and pulls the drop quite spherical. The smallest surface possible for a given volume is spherical. Raindrops are absolutely spherical. If they were not, there would be no rainbow, for the light would not be refracted at the proper angle to give the colored bands.

Who has had a drop of water fall down the back of his neck? Suppose the skin were very strong. Suppose it held a cupful before breaking. Fortunately, the skin is not very strong. In shot-making, the melted metal is poured through a vessel with holes, and the round drops fall into water. A shot-tower is a "gigantic shower-bath."

The surface film of water does not enter narrow spaces. A piece of wire gauze floats on water. Put some water carefully in calico (185:7); touch it underneath; the water now runs through, as the water film is below.

In wet weather, sometimes the canvas of a tent (185:8), where the water film had closed the pores of the canvas, is touched, bringing the film to the underside. The dripping water soon makes everything unpleasant. Mercury alone has a stronger surface film than water; it stays in muslin.

The surface film wets some things, and not others. Glass is wetted by a water film, but not by a mercury film. Water will not wet oiled or greasy surfaces (185:5). It wets threads of string or wool. Place four threads in a vessel of water (185:13); when wet, lift one end over into another vessel; the siphon filter empties the upper vessel. The threads will empty the former vessel.

Water does not readily wet a dusty surface (185:5c); see many water spheres dash away from a street watering cart. See drops on velvet (185:4). Ladies sometimes shake jackets when reaching home after a shower. Why? Ink spilt on a table-cover with hairy pile remains in large drops; it can be lifted in a wet spoon.

In pouring liquid into a narrow bottle, and in scientific work, the liquid is run down a rod (186: 13a-c). The film really forms a tube down which the liquid runs.

Tie the ends of two safety matches (186: 1a) with cotton to form a square — opposite sides matches, and opposite sides cotton. Needles stuck into matches serve as handles. Dip the square into soapy water; draw it out at one edge. A film contracts and pulls the cottons into convex curves.

Bend thin wire into three sides of a two-inch square with a handle (186: 1c). The fourth side is a loop to slide up and down. Tie cotton on the fourth side, opposite the handle. Draw the square out of soapy water; the contracting film lifts the fourth side; pull the cotton down; again it lifts; pull it down, and so on; the contracting film is elastic.

Make a wire ring (186: 1d), two inches across; tie cotton loosely across it; draw the ring from soapy water; the cotton lies irregularly. Break the film on one side with a hot nail. The cotton is drawn tight. Use another wire ring (186: 1e) three inches in diameter. Have a small cotton ring. Draw out a film as before. Dip the cotton ring in the soapy water, and drop it on the film as in *a;* pierce the film within the cotton with a hot nail. The cotton becomes a circle, and runs round inside the wire circle if moved about. Soapy water is used when blowing bubbles (186: 2).

Bodies that raise the film (straws, 186: 6 abc) are really beneath the surface. Such objects, if close, lie side by side. Similarly, pins depressing the film about half an inch apart come together. An object raising the film will not lie alongside one depressing the film; likes attract and unlikes repel.

Invert a bottle of water; water runs out; invert a narrower-necked bottle, water runs out; invert a very narrow-necked bottle, water does not run out (186: 14a); or a little runs out, and then stops. Jerk some water out. Fill it again; invert; the film forms across, and air presses up; the water does not run out. Invert the ordinary bottle again; water runs out; fill it; place a piece of paper (186: 14b) on the surface; invert; water does not run out.

With regard to capillarity (186: 9-11), the narrower the tube the higher the water (11) rises or the deeper the mercury (10) sinks. Candles (3), lamps (4) are kept sup-

plied by the liquid travelling up the wick; so towels dry, and blotting paper removes ink (186: 12).

A piece of camphor fixed to a small boat (186: 5) dissolves more on one side than another. As camphor solution has a weaker film; the contraction of the stronger water film pulls the boat about in a remarkable manner.

Place a drop of water on clean glass. It spreads out. Hold a piece of hot iron above the drop; heat weakens the film there, and the rest pulls outwards. On a clean pane put a drop of water; place another pane on it; it is easy to slide one over the other, but difficult to *pull* them apart.

The stronger water film pulls a weaker oil film over it. On a perfectly clean water surface, a little oil should cover a large pool. A *clean* water-surface, however, is unknown. One ounce of kerosene is used for fifteen square feet in mosquito extermination. A bag dropping oil suffices to spread a film on a troubled sea; it keeps the waves from breaking.

B.—WATER-FILM IN RELATION TO ANIMALS AND PLANTS.

Many animals live on the film, and should be above the water. Pond measurers (121: 4; 187: 1) and pond skaters (121: 3, 187: 2) are carnivorous bugs, obtaining a living on the surface of ponds and skating safely on this level, smooth surface. The mosquito as already described (119, 120) makes use of the surface at all stages, egg (187: 6), larva (6^{I}), pupa (6^{II}), and adult (3). Springtails (92: 1; 187: 4, 4^{1}) are common on the film; they jump many times their own height. Springtails appear in great numbers on temporary puddles after rain; evidently they have been washed from the plants and soil about. The lighter-colored individuals have probably recently moulted. The velvety bodies cannot be wetted by water.

The whirligig beetle (105: 6; 187: 5) is one of the most perfectly adapted of all insects to a pond life. The hind feet are folding paddles (85: 6, 7). The shell is water-repelling, and the insect floats with dry back at the surface. If alarmed, it goes down, taking a bubble of air (87: 8) with it. Other animals live below the film. Hydra (72: 1; 187: 7), the freshwater polyp, usually stands on weeds with the aid of the sucker-like disc at the end of the

body. It travels by looping over, standing alternately on its head and on its sucker; occasionally it loops on the film.

The larva of the soldier-fly (187:8; 118:8) holds, while breathing, to the surface with the aid of a beautiful coronet of hairs. Pond snails (187:9) skate under the film.

PLATE 187.—WATER SURFACE AND LIVING THINGS.

Animals that should live on one side of the film may find themselves prisoner. Water fleas (187:10; 79:9), with water-repelling shell, fall victims in great numbers when placed in a shallow dish. The swift-moving, restless water-mite, *Hydrachna,* may get one or more limbs through the film; it is then caught, and rushes round the aquarium just under the surface until a weed or obstacle helps it to pull away. Similarly the slow-moving, comparatively large Scale-tail (*Lepidurus*) may be caught by the end of a limb On the other hand, emerging adult mosquitoes (187:13) are caught in hundreds and drowned. The house-fly (187-14), with its short feet, cannot walk on the water film, and is caught, though it may struggle to the edge and escape.

Earthworms (187:15) are sometimes found in spoutings, and the supposition was that it rained worms. The worms common on asphalt paths are probably sick worms flooded from their burrows. The worms in spouting probably crawled up the damp surface, held on by the film. The writer has often had worms climb up the inside of a Mason's jar containing very little water.

Diving spiders (187:16), with hairy body, that cannot be wetted, take air down to a "diving-bell," to which they retire to breathe. Many minute animals, such as Cyclops (187:17; 79:4), may be held suspended in a drop.

The rufous and white-shafted fantails make a beautiful little nest, suggesting a wine-glass without the foot (187:8). This possibly serves to drain water down from the nest.

The long pointed leaf of the eucalypt (187:19) serves to drain water down to a point; it drops off freely, leaving the leaf dry for work in damp weather. The apple leaf (187:21) is wet above and dry below. Grass leaves and cabbage leaf remain dry; the water, in wet weather, forming in drops, which do not prevent the leaf from working. Duckweed (187: 24) and Azolla (187: 26; 54: 3) are common pond plants, the upper surface of which is dry, while the under surface is wet.

The Lady's Mantle (187:27; 16:9) uses the water film; a large drop of water in the partly folded leaf is probably a protection from grazing animals. Chickweed has a "staircase of hairs" that conducts the water downwards. The Starwort also has dry terminal leaves.

CHAPTER XXXVI.

POND-LIFE.

Ponds are of two main kinds, permanent and temporary. A permanent pond is a self-contained world. Food is derived ultimately from green plants. Floating are the long fine threads of an alga, *Spirogyra,* the "frog's blanket" (188:5). It consists of a series of cells suggesting drain pipes; the green part is arranged spirally in each cell. The erect "stone-wort" (6) also an alga, has the male cells below the fruit-like, spore-producing structures (6^1). The water milfoil *Myriophyllum,* myriad leaf (11) grows near the margin. All three plants may be submerged. How do submerged plants obtain air? Warm pond water in a test tube (189:1a); soon bubbles of air appear. A glass of cold water in a warm room shows such bubbles. Warmer water dissolves less air, and some separates out as bubbles. Fish and these plants breathe air dissolved in water. Carbon dioxide, necessary for starch manufacture, dissolves in water. Heat pond water in a flask (189:1b); the lime-water in the lower vessel becomes milky, due to carbon dioxide. Evaporate pond water on clean, thin glass (1c); a stain of dissolved soil material is left.

Hold a bottle of pond water to the light; tiny greenish balls may be swimming about; these are the wonderful Volvox which some scientists call an animal and others a plant. It has green, makes its own food, and behaves in other ways as a plant. Still it and some other plants move about. Under a microscope, the surface shows many cells, each feeding itself and having two whip-like processes which cause a rolling motion. Volvox, a wonderful colony of possibly 12,000 cells, is an interesting connecting link between one-celled animals (Protozoa) and many-celled animals (Metazoa), as well as between animals and plants.

Floating duckweed is multiplying rapidly; the flattened stem turned up in some parts, down in others, raises the water surface here and depresses it there. What effect has this? Two straws with raised water surface attract

(186:6); two floating pins with depressed surfaces also attract (186:7). A pin and a straw repel each other (186:8). The duckweed, repelling here and attracting there, spreads over the pond. A lead pencil dipped amongst duckweed lifts plants held to it by the surface film; water-birds (47:5) carry duckweed to new ponds. The floating water-fern *Azolla* (54:3; 188:12) may suggest a gravel path. On its crowded leaves rain-water forms drops; the pores are not blocked. If the plant goes below, the film encloses some air which refloats it.

Plate 188.—POND PLANTS.

The bulrush *Typha* (4) is called the cat's tail, a name wrongly applied to water milfoil. The brown velvety tail-like structures contain many seeds (46: 17). Starwort, *Callitriche* (8), an almost cosmopolitan pond plant, is rooted in shallow water. The terminal rosette leaves are not wetted; the flower is minute. The clover-fern, Nardoo (188: 7; 54: 2), a water-fern whose sporocarps are used for food by Central Australian aborigines, grows about the Yarra River, at Kew.

Two pond plants may be pests. Elodea (188: 10), of America, has spread throughout the canals of England. It is figured so that it may be recognised if seen. The Water Hyacinth (188: 9), of Florida, spread from Queensland, has blocked rivers.

The stems of pond plants supported in water need little strength and no long tubes to conduct water; no material is wasted on a thick woody stem. The stem of the water milfoil (188: 11) has spaces suggesting those of a wheel. One troublesome "pond weed" (*Potamogeton*) (188: 2; 35: 10) causes much weed cutting in ornamental lakes. "Water-lilies" (40: 10) have large floating leaves with long leaf-stalks and dry upper surface. Some plants float in favorable weather, and sink in cold weather.

The numerous male flowers of the famous Vallisneria (188: 1; 35: 6) sometimes suggest white powder scattered on the Melbourne Botanic Gardens lake. Many plants inhabit ponds so well provided with the necessaries of life, therefore there are many animals also. Pond water teems with life, seen when examined microscopically.

Pond animals are many and varied. Each class of pond—deeply-shaded, sunny, permanent, temporary, transient—has its own type of life. The dainty "water-fleas" (*Daphnia*) (187: 10; 79: 9) which, from their jerky motion, have received an inappropriate common name, have great powers of reproduction. When conditions become unfavorable, as when pools are drying up, males appear, and two "winter-eggs" (89: 17) are produced in the brood pouch (89: 17). These may be seen in shells in a dry pool. Mr. J. Searle, the well-known naturalist, suggests the name "resting eggs." They retain vitality until favorable conditions return.

Another tiny free-swimming pond animal suggests a full stop; it is a relative of Cypris (79:8). If alarmed, it closes the shells and sinks. Estheria (79:7) also has shells sug-

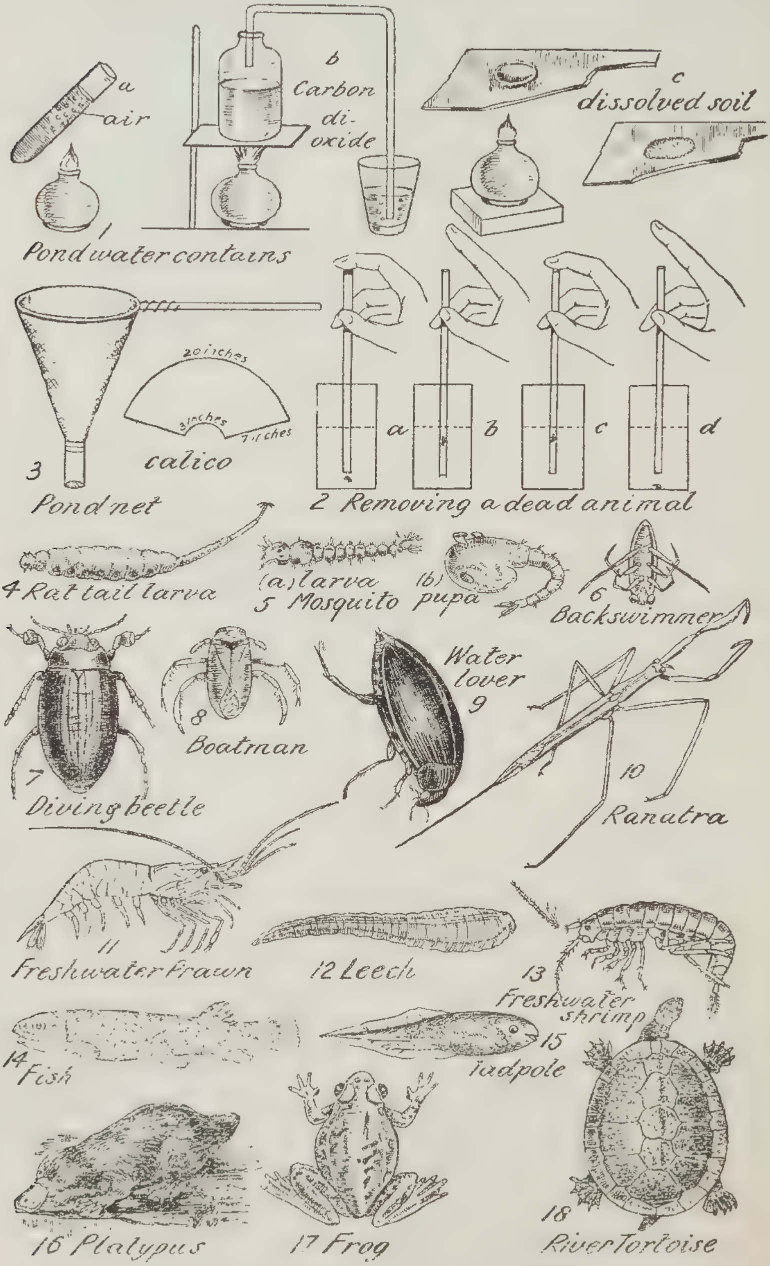


PLATE 189.—POND ANIMALS AND EXPERIMENTS.
5 larva of the malarial mosquito—Anopheles.

gesting cockle-shells. The "scale-tail," *Lepidurus* (79:6; 187:12), has sixty-three pairs of limbs used for breathing and locomotion. It falls a prey to water bugs, which suck blood from the leaf-like breathing legs. The minute one-eyed Cyclops (79:4; 89:18; 187:17) swims with its long feelers. The active freshwater shrimp with tail bent under (189:13; 79:1) is flattened from side to side; it is allied to the sandhopper found under dry seaweed on the beach. Freshwater prawns (189:11) are often called shrimps.

Insects, though common in ponds, are not fully adapted to a water life; all breathe at the surface. Air-bubbles are taken down by many beetles (87:8); whirligig beetle, diving beetle (189:7; 105:7) and water-lover (189:9; 105:8) are common. Many water-bugs are found, including the stout water scorpion, *Nepa* (121:8), the elongate Ranatra (87:16; 189:10), the boatman (189:8), and the back swimmer (189:6). Slow "pond-measurers" (187:1; 121:4) and active "pond skaters" (187:2; 121:3) living *on* the water, are also bugs.

Dragon-fly larvæ "mud-eyes" ($97:1^{ii}$) abound in permanent lagoons. They breathe (87:3) by taking water into the posterior end of the alimentary canal. The forcible expulsion of this water drives the animal forward; water-tigers (87:4) larvæ of diving beetles, breathe similarly. Damsel-fly larvæ (97:2) breathe (87:7) by means of three leaf-like gill-plates. Some May-fly larvæ (98:1) have a strange history, and perhaps two years in a dingy pool for a day of life in the free air. Stone-fly larvæ (87:9; $98:2^{ii}$) often live under stones in running water. The "water casemoths," caddis-fly larvæ (98:3; 87:12), in their peculiar homes, are abundant. A naturalist took the case from one and gave it plates of transparent mica. It built its home with these, thus providing an opportunity of studying its habits. The "rat-tailed larva" (189:4; $118:4^{i}$) of the drone-fly, has a telescopic breathing-tube. Mosquito larvæ and pupæ (5) are treated elsewhere. A blackish, powder-like mass on water in a rut is moving; it is composed of tiny insects, "spring tails" (92:1; 187:4, 4^{i}).

Worms of many kinds are associated with ponds. The hair-worm *Gordius* (74:4), occasionally found in tap-water, passes part of its life in a water-beetle. The five-striped leech (189: 12) is used at hospitals. Small red worms, *Nais*, wave continually in filthy water where oxygen is scarce.

Pond snails (132: 4; 187: 9) skate beneath the surface, while red water-mites (128: 6; 187: 11) race ceaselessly. Water spiders (129: 8; 187: 16) have wonderful diving bells in the grassy depths apparently so short a distance down.

Vertebrates, animals with bones, receive little attention from pond-hunters; fish (189: 14), tadpoles (189: 15) and frogs (189: 17; 139) are well known. River tortoises (189: 18)—reptiles with bones fused with the shield outside the body—are related to the turtles of tropical seas. Platypus and water rat (152: 16) represent mammals.

In a garden there is a succession of flowering plants and in a pond there is a similar succession of animals and plants; some develop early, others then have their turn.

A pond net (189: 3) may be made with fencing wire bent into a six-inch circle, a piece of art muslin or cheese cloth (189: 3) threaded on the wire, a bottle fastened in the apex, and a handle. It concentrates pond animals and plants while being drawn through the water. By holding it up, the catch can be inspected; pour into a jar of pond water filled to the widest part; add some pond-plants and a few animals. The water should *not* be changed; refill with pond water occasionally. If green plants coat the jar, put it in a shaded place and add pond snails, which eat the green plants. Some sand and charcoal in the bottom will often be useful. Avoid overstocking. If the water becomes cloudy, siphon some off with a rubber tube, and add pond water. If anything dies, remove it (189: 2). Several glass jars of pond life are more convenient than one large aquarium; medicine bottles suffice for some small forms.

The marvellous and interesting microscopic section, being outside our scope, is omitted from this general treatment of a delightful and easily-managed branch of study.

The Blue-faced Finch.

APPENDIX.

NATURE-STUDY IN EDUCATION.

A.—General Considerations.

The child has learnt much before entering school: he is interested in, and full of curiosity concerning, things about him. Nature-study aims at continuing his natural method of learning and developing further his interest and curiosity. It brings into school not only this natural method but the familiar things of his environment, thus imparting to school work an atmosphere of interest and reality. School knowledge, in the junior department, now centers largely about those things that interest the child. In the past, school life was divorced from the nature the child knew, and the teaching methods in vogue often killed his interest and quenched the spirit of enquiry innate in all children. As nature-study is so full of interest and is not an examination subject, it affords relief from more formal work and provides relaxation and pleasure. In this subject at least, teacher and children may follow their interests.

The definition of nature-study best suited to our outlook is by Professor Lloyd Morgan:—" Nature-study is a process whereby common things and events acquire a meaning." This gives the direction, scope, and purpose; it indicates that nature-study is concerned with the common things and events of the child's environment and that its purpose is achieved when such have a " meaning " to the child.

This objective can be secured by about one hour of school time weekly. As no added result ensues, it is an educational waste to devote more time to it. Nature-study occupying one twenty-seventh of school time is, from a time aspect, a minor subject; yet it produces an effect important to child and nation.

Australians of older generations say that nature-study was unknown in their day. These Australians, however, had their school drilling in the "three R's " and enjoyed an outdoor life in bush, scrub, or open country, now largely occupied by towns and farms. To give present day children as good a chance in life, the study of what remains of the natural environment (nature-study) is necessary. Many adults, however, regret that the education of their youth gave little knowledge of the wonderful world about them. Who has not missed that knowledge and enjoyment as he advanced in years? All wish their children to have some of the joys of the nature-lover.

However, times have changed, the world has moved on, and what was a sufficient training twenty years ago is not sufficient in this age of aeroplanes and wireless telegraphy. To give our children as good a chance relatively as we enjoyed, they must be better equipped, and have more power of fronting facts and thinking for themselves.

Concerned with the out-of-school life when the child is free from the direction of the teacher, nature-study makes the environment a factor in education and replaces to some extent also the vocational training formerly provided by the family life, but which, under the modern factory system, is lost to the child.

The one main object of education is to produce a self-educating person. Nature-study with its vast field for interest lays the foundation of this desirable habit for the observant child. He develops power to study natural things for himself and acquires power to extend this habit to other subjects.

Our aims in nature-study then are to continue the natural method of learning and to enable a child to see and understand; he should see for himself, think his own thoughts, and enjoy the natural beauties and operations about him. Incidentally, he develops power to express his thoughts in speech, drawing and writing. Thus is attained the purpose of nature-study as set out in the official course of study, namely that a child shall "see, think and tell" for himself. This training does not in any way lessen the value of his work in the "three R's," indeed, it increases the value of that work for the child brings to it an enquiring and experimenting mind and thinks independently on the matter in hand.

The wide scope of nature-study renders it impossible for teachers or even scientists to know every branch. Many primary teachers of twenty years ago considered they could not afford to say, "I do not know." It often happens in nature-study that no one knows, for much has not yet been scientifically described, and much that has been described is not in an accessible form. Teachers, fortunately, have to admit they do not know, and that develops in school the proper attitude of enquiry. Even if one does know, the attitude in nature-study should be "discover much for yourself." All children are not interested in the same subject; but, fortunately, the field is wide. By studying a variety of subjects, each child will probably become interested in at least one branch. He will observe in this for himself and develop the spirit of enquiry further.

For country dwellers, such as agriculturists, graziers, dairy-farmers, and orchardists, experimenting and recording habits and an observant eye quick to detect the needs of plants and animals, and to recognize pests and adverse conditions, are desirable; the nature-study habit is a valuable adjunct to the formal studies. Nature-study has a practical value especially in a new country like Australia, where plant and animal friends and foes are not yet known. Many animals, such as the dragon fly and toad, were once dreaded, but have proved valuable. The discovery of an enemy for the destructive codlin moth, if it proves as successful as the lady bird that controls the cottony cushion scale, will mean much to Australia and the world generally.

Nature-study also has an educational value. The fourth R—reasoning—is important How many men with little of the three R's have become leaders amongst men? They owe their success, not to their knowledge of the three R's, but to their power of fronting facts, forming correct judgments, and depending on these judgments They can see and think for themselves. Nature-study, concerned with seeing and thinking, assists in developing reasoning power.

Nature-study, while taking a limited amount of school time, helps other subjects. Composition, oral and written, is assisted directly. The children, having much to tell, develop the power to express thoughts suitably. Drawing is also assisted; new things are studied and expressed by drawing, which implies accurate observation of form and structure. Geography is helped largely; just where physical geography ends and nature-study begins is not easy to say; each helps the other.

Science is also helped materially. Nature-study suited to children up to eleven years of age is a good preparation for science work later. School agriculture is applied nature-study. In practical agriculture, the methods of other lands are not necessarily successful here. Australian conditions, with excess of sunlight and sometimes a deficiency of moisture, must be studied. Who can study them better than interested nature students?

A person sees only that for which there is already a basis in his own mind. If artist, farmer, sportsman, botanist, and bird-lover gaze over the same valley, each sees a different picture, though the same image is formed on the retina of each. We see with the brain. The weekly nature-study lesson is necessary to provide a child with ideas and to train him in seeing. The power is then applied out of doors.

In nature-study, there is no danger of all children being cast in the same mould. How different the nature-study in schools of mountain, shore, and forest regions or of mining and orchard districts! Profit and pleasure await all in the study of their environment; there is freedom in this subject at least.

Rare plants and animals are of less use in nature-study; common things are common because they overcome the rarer ones in the struggle for existence. They are better adapted to their environment. Hence common things are often more interesting than are the rare things. Usually rare things are sought, and often more is known about them than about the common forms around us.

Superficial or undirected observation is a possible danger to nature-study. Some keen-eyed children may give much oral composition on the external accidentals of an apple such as a streak here and a dot there. This might produce good oral composition, and possibly keen observation; but it is doubtful if it is nature-study, which is "a process whereby common things acquire a meaning." The meaning of the apple is connected with seed-scattering. It is doubtful if the undirected observation of an average child would lead him to discover the meaning of common plant or animal structures. Observation is the first step only. To see, think, and tell is our method. The superficial observation that allows glib talking on almost any subject is the antithesis of nature-study, where the students waits to see and think, before he can begin to tell. Again, it has been well said that observation is nine-tenths inference. A child does not know what he is looking at. He is heir to all the ages, and cannot be left to discover everything for himself.

Many students are repelled by the high-sounding, technical terms sometimes used, but nature-study is not concerned with such. Each science, even education itself, has developed a technical language. A student cannot acquire this without expending time and effort. No man can use technical terms in all the branches of science drawn on by nature-study. Ideas first, words afterwards, is good educational practice. In nature-study the child gets ideas; later, in his science course, he can get the technical terms. Even scientists protest against this highly specialized language. Professor Scott Elliot, in his "Nature Studies," says:— "The terminology of Botany is fast becoming a sort of Chinese alphabet, which will require so much time to master that nothing of a lifetime will be left in which to use it in the study of Nature." The use of scientific names by non-experts is not desirable, even if it is possible. Professor Ewart, Professor of Botany, Melbourne University, and formerly Victorian Gov. Botanist, in the preface

to the "Plants Indigenous to Victoria," Vol. II., says:—"This issue affords a striking comment upon the stability or rather the instability, of scientific biological nomenclature. Out of the plates struck off forty years ago, only nine names out of nineteen remain the same to-day. Out of the whole series (31 species) no less than twenty names have undergone alteration. One plant had its name altered no less than five times. Two plants have been re-baptized three times, and seven twice. It is no exaggeration of the truth to say that, at the present day, the popular names of the plants are more stable than the scientific ones." An example of similar confusion and instability on the animal side is given under the Monarch butterfly (page 265). Australian bird names are even more striking; the common names are stable, the scientific names are chaotic. There is little place for technical terms and scientific names in the nature-study of children of eleven and under.

With reducing working hours and increasing leisure, education for leisure becomes more necessary. Nature-study is an ideal hobby for leisure. Individuals with a love for bird, flower, and open fields shun street corners. The strain and nervous tension of city life are increasing; nature-study relieves tension by enticing city dwellers to the country. The week-end habit is already a feature of modern life. Hundreds of city toilers and professional men pay week-end visits to the country; "back to nature" is their cry. Rural population is a pressing need in all countries. Nature-study, by developing interest in river, animal, plant, and mountain, helps to make people more satisfied with country life, thus tending to check the drift citywards, and luring many to the full, free country life, where trees, birds, flowers, and rocks stimulate interest and become friends.

Australia, well described as the "wonderland of the scientist and nature-lover," and so long isolated that it has become a "great natural museum" full of "living fossils" and animals and plants of great scientific interest, owes something to the world generally. Nature-study assists in developing the requisite interest in, and the knowledge of, these remarkable animals and plants that should be saved for posterity.

A love of truth will surely result from nature-study, which helps to develop the seeing eye, the hearing ear, and the understanding heart. In nature-study, reliability is the key-note. It helps to produce the citizen the Empire needs, reliable, resourceful, experimenting, observant, mindful of the rights of others, standing firm to the right and true, and not misled by glitter or appearance. Though taking little school time, nature-study is worth its place in the course of study.

B.—Nature-study as a School Subject.

The teacher's aim in nature-study is that a child should "see what he looks at," think about what he sees, and then express his thoughts suitably. The aim is expressed simply in three words—*see, think,* and *tell.* Children will see, think, and tell if they are *interested, e.g.,* if they have that which so fills them that they must tell. Hence interest in what is around us should be developed. A fresh study regularly each week and a short daily period to secure continuity of work will develop this interest. *One* lesson each school week should be given without fail. The losing of the weekly lesson or study through school emergencies

is a serious drawback. Geography receives three or four lessons weekly and some of the weekly nature-study lessons. If, when the nature-study period has to be omitted, the succeeding geography period is devoted to nature-study, it interferes little with geography, but renders success in nature-study possible. Six lessons in ten weeks will not achieve our purpose.

Even untrained teachers can secure the necessary specimens and experiments, prepare and give a weekly lesson on a fresh topic, and take the morning talk regularly. Regularity and freshness are the essentials for success. There is such interest in the subject itself that failure when regular fresh work is given is practically impossible. In an extended experience, no case of failure has been met when work was fresh and regular.

A half-hour study weekly introduces a subject to the child, reveals something of interest in it, and ensures that he *sees* what he looks at. In the six years about 250 subjects will thus be studied. The child will introduce himself to other animals and plants, and, by comparing and contrasting them with objects previously studied, will discover much for himself; he will utilize any opportunities for observation. Revision is out of place in class nature-study, except where some fact is required as a foundation for further work. Instead of giving several studies on one subject, it is usually better to give one lesson on each of several subjects, thus introducing fresh ideas. Even if there is room for a second lesson, it is often better to take a fresh topic. Sometimes, however, fresh phases of the subject require treatment; then give it.

While each teacher develops the branch in which he is most interested, he should not confine his course to that branch. All pupils may not follow him in his special interest. Some love birds, others flowers, some rocks, others are keen on the glories of the sky—nature's picture book. All should receive stimulus and introduction. Therefore in his course let the teacher include studies in many branches suited to his locality.

While allowing much freedom, two restrictions have been found necessary:—(1) Fresh topics and ideas must be left for the higher grades; and (2) the work of the middle or higher grades must not be a repetition of that done before. Most subjects, *e.g.*, mosquito, are as suitable for a high grade as a low one, but they are not suited to the child in successive grades. Some subjects are taken twice. It is good for higher grade pupils to study occasionally a subject treated in the junior grades.

Correlation is a wise principle in education. Some good nature-studies do not correlate well; these should not be omitted from the nature-study course on that account. Lessons should often be taken out of doors. If the school time table were adjusted to bring nature-study and geography together at the close of a meeting, a monthly or quarterly excursion could be easily managed. Geography and nature-study combine readily.

There are two distinct steps in any nature-study. The child first examines the material for himself, forms his own ideas about it, and becomes accustomed to movements and structures. A lesson during this stage is pleasant or profitable neither to teacher nor pupil. It is useless to give out active animals such as snails and expect a satisfactory lesson. The teacher will have trouble with the best class possible unless the children have previously become

familiar with the movements. When attention is directed to the shell, if the snail protrudes its eye not previously seen by the pupils, few will see the shell. In the second stage, the child desires to tell what he has observed and to hear what others have discovered. A lesson, now that he is *ready* for it, is a pleasure. Though the pupils may have no discovery to announce, movements and structures no longer engross them, the interest in the specimen does not clash with the interest in the lesson. The attention of the class will now be better than during ordinary lessons.

That certain animals and plants will be studied later should be announced several weeks ahead. Children then use opportunities for preparation. Do not expect each child to bring specimens; some parents object: some children neglect the matter until too late, and then worry the parents. Allow volunteers the honor of supplying the rest before the day of the. lesson. If material is scarce defer that study and take the second announced. Include topics specially suited to the locality. Such are omitted from a general list, suggesting studies for 2200 schools situated by mount, and stream, and sea. Many teachers choose plants and shrink from animal life. Some forget that plants have life. Dead specimens are unnecessary, and, in fact, are often nearly useless. It is the living, working organism that is beautiful. Nature-study develops a regard for the rights of others, and a respect for the life of both animals and plants. A dead specimen means generally a dead lesson.

Some authorities object to "sipping," and want "systematic" work following the order of science. That is impossible, and even if possible is undesirable. Few, if any, elementary school teachers know the scientific order of the several sciences drawn on, few can find the material to illustrate the scientific order, and few localities provide that material.

Professor Liberty Bailey effectively answered those who demand "continuity" by remarking that nature "has a brook and plants and toads, and bugs, and the weather all together." Though man would treat these under different sciences, yet, in nature-study this is the natural grouping. To the child, there is but one science, one nature. Regular, fresh work suitable to the locality and season should be taken. The work must be seasonal. The cherry is not a winter study, nor is frost a midsummer study. The work must also suit the locality; shore life is a study unsuited to inland districts. A study of granite is not usually suitable to a locality remote from granite areas. Seasonal and suitable to teacher, children and locality are the requisites.

Some authorities desire much apparatus. There is, however, abundance of naked-eye material. The course suggested requires little special apparatus, material, or skill in manipulating apparatus. The child should acquire the habit of noting unconsciously what is going on. He hears the singing lark while those not interested hear nothing. He enjoys the beauty of the sky and spring flowers while walking to school. If he has the nature-study habit only when fully equipped with apparatus and in a special locality, then nature-study has failed. Wayside plant and lonely road should have interest and meaning as well as the school garden, which will not be neglected in nature-study.

With the usual school class the microscope is impossible, it belongs to the well-equipped laboratory. A parent having a microscope might introduce his child to the marvellous world of the

minute, but should not close his eyes to the equally marvellous world of the commonplace about him. A magnifying glass for older children may be encouraged, though it is not indispensable. Home-made apparatus for simple experiments gives children as much pleasure and profit as costly appliances often difficult to use. The home-made net catches pond residents suitable for children, though it misses the microscopic prize of the scientific pond-hunter. A wide-mouthed, corked bottle for each child could be kept at school. Spiders, insects, snails, and pond-life are easily examined in these. The animals could afterwards be liberated in a suitable place.

Lessons should always be fully illustrated; there should be a constant appeal to the thing itself to confirm or correct each point. Observation and study must be based on reality. The facts must be right, though not crammed in. A person requiring later to know one could gain the information from the specimen for himself. If one of the three weekly composition lessons follows nature-study, then the pupils, while full of the subject, can write an independent composition on it. By reading three compositions, one could gain an idea of the lesson.

A large locality map should show local geographical features known to the children in the field. Senior pupils should know the interest and probable formation of each; they should also know the principal district rocks. A tree and wild-flower map should be gradually compiled, and the common plants be known to teachers and pupils. The map should show the principal ponds and the main plants and animals of each should be known. Nature calendars, giving dates of appearances of birds, insect and flowers, add interest and direction to outdoor observation. Teachers should leave helpful suggestions and maps for their successors. Then, in a few years the locality will be known and interesting to all concerned. On completing his nature-study course, each child should know his own locality, and the physical features, rocks, chief animals, and plants of it. He will not then fail to be interested in his surroundings and in other districts when he visits them.

A simple test of the success of nature-study work is this: if the work is a pleasure to all concerned, it cannot be wrong; if not a pleasure, it cannot be right, though much time and trouble be taken to provide abundant material and to give good lessons. If pupils discover things you know nothing about, be happy, and think, "What a good teacher am I," for, as Bailey remarked, "the best teacher of nature-study is the one whose pupils furthest outrun him." Enjoy the work, and let your pupils run on.

C.—A Suggested Course in Nature-study.

The nature-study of the lower and middle school is usually replaced by science in the higher grades. Children from five to eleven years of age take nature-study while children of twelve and upwards usually study one branch of science. In rural schools applied nature-study in the form of agriculture is taken with children over ten years of age. The work involved in the suggested course is mainly suited to children under twelve years of age. Enough material, however, is provided to carry the nature-study course through to fourteen years of age as desired by some teachers. The dates on the suggested course suit fairly well a normal year in Melbourne Subjects should be re-arranged to fit the season and locality. The reasons for differences would be noted with interest.

AN EIGHT YEARS' COURSE OF STUDY.

SUGGESTED TOPICS.

During February, grade teachers should draw up a suggested series of **weekly** lessons for their grade for the year, compare the series with those of the grades above and below, and see that each topic selected is suitable to school and locality, and fresh to the pupils. Schools situated near the sea should have several beach lessons in each grade. The following suggestions name many seasonal topics for each week. Rearrange the order to suit season and locality. It has been found **necessary to impose two restrictions on a free choice of subjects.** Fresh lessons must be left for Grades VI., VII. and VIII., and repetition of lessons given in lower grades must be avoided. Give the lessons asterisked (if suitable), and, for the balance, substitute as many local subjects as possible, provided that the work of a higher

Week ending about—	Grade VIII. Age 13 years.	VII. Age 12.	VI. Age 11.	V. Age 10.
Jan. 29	*Dry fruits ..	Prickly pear or Cactus	*Seed scattering..	*Explosive fruits (gorse, etc.)
Feb. 5	*Edible fruits ..	*How plants reduce loss of water	*Water and life or Transpiration	*How seeds are protected in fruits
,, 12	Seaweeds or Swamp plants	Crayfish or Crabs	Aphis or Stinging Animals	Univalves, Dock or Oleander
,, 19	Fish (kinds); Drought & plants	Beetles or Sea-mats and Sea-ferns	Scale insects or Sea-Worms	Bivalves, Fish or Mussel
,, 26	Wingless insects or Shore formation	White ant or Eggs of sea animals	Ladybird and L.H. or Head-footed animals or Apple	Shrimp, Casemoth or Goatmoth
Mar. 4	Insect heads and bodies or Shore vegetation	Galls or Straight-winged insects	Grape vine or *Migration of birds	Ant or Boxthorn
,, 11	Insect wings; Bacteria and decay; Bird migration	Ants and other animals or Many-legged animals	*Mosquitoes, I.	Ant homes and L.H.; Mantis
,, 18	Insect legs; Colors of animals	Moulting of birds or Wasp	*Mosquitoes, II.	Blackberry plant; Rose plant
,, 25	Insect mouth parts or Mimicry	Maize or long-feelered grass-hoppers	*Equinox place & time of sunrise and sunset	Cockroach or Sunflower
Apr. 1	Destructive insects or Bird families	Scale-winged insects or Thistles	*Mould and mushroom; Burying beetle ..	Spider or Twining plants
,, 8	Beneficial insects or Cause of winds	Fig or Vegetables	Fall of leaf (expts.) †	Spiders' webs and homes
,, 15	Seedlings or Cyclones and anti-cyclones	Sucking-beak insects or Rain and life	*Germinations (onion, sunflower, maize, pine, date)	*Pea-seed
,, 22	Food constituents or Growth in nutrient solutions	*Percentage germination and seed-testing	*Seed leaves and uses	*Pea and wheat germinations
May 6	Fungi or Spiders	*How nature plants seeds or Earwig	*Feeding of plants (expts.)	*Conditions for growth (expts.)
May 13	Branching of trees or Variation.	Toadstools and puffballs	*Leaf arrangements & mosaics (exp.)	*Food (expts.)
,, 20	Wood and timber; Increase of animals and plants	*Dew and its causes	*Leaf shapes and edges (expts.)	*Work of leaf (expts.)
,, 27	Timber destroyers or Struggle for existence	Modifications and kinds of leaves	*Plants breathe (expts.)	*Leaves need light (expts.)
June 3	Vegetation & water flow or Balance of nature	Modifications of roots	*Kinds of roots & experiments	*Leaves and water (expts.)
,, 10	Eucalypts or How animals winter	Stems & ascent of sap	*Kinds of stem & experiments	*Work of root and osmosis (expts.)
,, 17	Granite or Moon or District geographical features	Evergreen trees or Pebbles	*Plants feel (expts.)	*Work of stem (expts.)
,, 24	Volcanic rock or Tides or Rainbow	Bark or Teeth of animals	*Solstice: place & time of sunrise and sunset	*Resident birds

* Lessons marked * should (if practicable) be given.

SUGGESTED TOPICS.

grade is not encroached on, and that past work is not repeated. No subject should appear more than twice in a six years' course, or more than three times in an eight years' course. Seed-scattering and fruits must be spread over the eight grades, therefore reserve seed-scattering for Grade VI. and fruits for Grade VIII. When Grades VII. and VIII. take nature-study in lieu of science, fresh work must be done by these grades. No subject is to be taken, unless it is amply illustrated with specimens and necessary experiments, and is suitable to season and locality. Give one lesson a week regularly. Some nature-study lessons are geographical, and geography will not suffer if the succeeding lesson, when a holiday or school emergency intervenes, is devoted to nature-study. Experiments in Grades V. to VIII. should be on hand from April until September at least. When an experiment has served its purpose, another should be substituted. **Announce each lesson at least two weeks in advance.** Use the second lesson if specimens are not available for the first; substitute local subjects; allow full freedom in the morning talk, except that it should not encroach on coming lessons; and make the work pleasant.

Week ending about—	IV. Age 9.	III. Age 8.	II. Age 7.	I. Age 6—4½.
Jan. 29	*Hooked fruits or Bathurst burr	Winged and hairy seeds	How plants drink or Milk	Summer or Cat
Feb. 5	Sponge or Marigold	Fruits that are not eaten or Pigface	Apple tree in summer	Thistle seed or Dog
„ 12	Starfish or Sow thistle	Couch grass; Looking glass bush	Apple ..	Plum
„ 19	Sea-urchin or Leaf miner	Tomato or Seaweeds	Peach, Grape or Cockroach	Water and forms or Housefly
„ 26	Grasshopper or Thistle	Pear or Sea-animals	Emperor gum moth or Galls	A live fish or Cricket
Mar. 4	Caterpillars or A dust storm	Aphis or A beach	Crabs or Seed-boxes	Casemoth or a Caterpillar
„ 11	Leaf-rollers or Cosmos	Insect homes or Scale insects	Shellfish or Mosquito larvae	Dandelion
„ 18	Snapdragon or Click beetle	White grub or Marguerite	Blackberry; Mosquito pupae	Ants and home
„ 25	Plants used for food or Weevil	Equal day and night	Sunflower ..	Autumn flowers or Thistle
Apr. 1	Cricket or Moreton Bay fig tree	Burrowing animals or Cupmoth larvae	Emperor gum caterpillar	Autumn leaves
„ 8	Bonfire salvia ..	Mushroom ..	Spider and web or Fig	Rose plant
„ 15	Dolichos ..	Growing wheat seed	Growing broad bean	Growing pea-seed
„ 22	*Autumn leaves ..	Virginia creeper or Chrysanthemum	Ivy or Robin ..	Growing acorn and carrot
May 6	Slater or Tendrils	Pepper tree ..	Apple tree in Autumn	Winds; Mushroom
„ 13	Clothes' moth or Hawthorn	Galls or Plane tree	Emperor Gum cocoon and pupa	Dewy and frosty mornings
„ 20	Prickly plants or Loquat tree	Sweet briar or Sky pictures	Rain and fog ..	Baby plant and growth
„ 27	*Eucalypt ..	Earthworm ..	Pond animals ..	Our teeth
June 3	Eucalypt friends	Growth of wheat	Pond Plants or Moon	Our fingers and toes
„ 10	Eucalypt foes ..	Trees in winter ..	Broad bean plant	Our senses
„ 17	Tree planting or Bark	Evergreen trees ..	Log of wood or Earthworm	Clouds
„ 24	Soil or Firewood	Shortest day ..	Apple tree in winter or Cow	Water and forms

† Lessons marked † should be illustrated by experiments working from April to September.

SUGGESTED TOPICS—*Continued.*

Week ending about—	VIII.	VII.	VI.	V.
July 1	Sediments or The solar system	Boiling of water or Arms and legs	Freezing of water; Plants sleep	*Wearing by running water
" 8	Limestone or Sky and stars	Frost and effects	*Deposits & flood-plains	*Carrying and depositing
" 15	Fossils or Quartz or Ignition point	*Meanders, billabongs, and river terraces	*Rivers and lakes	*Old and young plains & valleys
" 22	Rock weathering; Soil & sub-soil	*River capture ..	*Clouds ..	Surface of water, I.
" 29	Coal or Minerals; Skin and covering of animals	*Transport by running water	*Local geographical features or Southern Cross and N -S line	Surface of water, II.
Aug. 5	Crystals; Solutions; Skulls	Sand and clay or Waterfalls	Violet plant; Our sense organs	Our teeth or Bulbs
" 12	Weeds and plant foes or Flowers of trees	Cliffs or Drainage and vegetation	Horse and cow, Eyes of animals or Bird migration	Our arms and legs
" 19	Reserve materials; Springs & wells	Origin of soil or Bulbs, corms, &c.	Cat and Dog or Ears of animals	Snail or slug
" 26	How plants are protected; Order of vegetation	Composition of soil or Pine tree	*Wattle-tree; or Variation of Early Nancy	*Earthworm and soil (expt.)
Sept. 2	Reproduction without seeds or Leafless plants	Soil and water or Healing of plant wounds	Wattle-tree, friends and foes; or Orange-tree	*Bud - study or Weeds or Vine moth
" 9	Sunshine or Animals that store food	Spines, thorns and prickles; Nails, claws and hoofs	*Food-stores or Asparagus	*Oak tree or She-oak
" 16	Parasites or Leaf stalks & stipules	Twig study or Nettle	Sundew or House-fly	How plants spread without seeds or Rabbit
" 23	Orchid; Apple tree, friends, foes	Mistletoe or Dodder	*Potato or Iris ..	*Frog's spawn
Oct. 7	Color or Topography of a bird	Hen's egg and chicken	*Feathers	*Legs, feet, and toes of birds
" 14	Economic value or Food of birds	Wings and flight	*District birds in orders†	*Tails of birds or Birds' nests
" 21	Birds of Australia or Kinds of birds	Senses or Structures of birds	*Beaks and necks	*Songs and calls of birds
" 28	Arrangement of flowers or Composite flowers	Pollen - boxes or Fruit-forming	*Scarlet geranium	*Pea flower
Nov. 4	Duration and time of flowering or Buttercup family	Protection of pollen or A pond	*Nasturtium or Sage	*Wheat flower or Rye grass
" 11	Lichens or Eucalypt family	Nectaries or Pond plants	*Ribwort or Strawberry plant	Hollyhock or Gorse
" 18	Moss or Animal-catching plants	Scents of flowers; Pond crustaceans	Worker bee or Cicada	*Tadpoles or Duckweed
" 25	Liverwort or Bees and their habits	Lilies or Water-beetles	*Flower visitors or Cereals or Climbing plants	*Fruits of wheat and pea plant
Dec. 2	Ferns or How insects make a noise	Grasses or Water-bugs	Dandelion plant or Froghoppers	*Frog or Diving beetle and larva
" 9	Plant colonies or Reptiles or Bat	Pod-bearing plants; Aquatic larvae	Bracken fern or Insect homes	*Vine caterpillar or Clematis
" 16	Surface of water and life or Silkworm and silk	Two-winged flies; Breathing of pond animals	*Potato plant; Butterfly L.H.; water fleas	Butterfly and moth or Water boatmen or Shells
" 23	Twilight or Disease - carrying animals or Mulberry tree	Veil-winged insects; Ivy or Sea Crustaceans	Travelling seeds or Dragonfly and L.H.‡ or Sea Animals	Scarlet pimpernel or Rockpools

† Consult "An Australian Bird Book."

SUGGESTED TOPICS—*Continued.*

Week ending about.—	IV.	III.	II.	I.
July 1	Crow, Magpie or Magpie-lark	Starling or Blue wren	House and tree sparrows	Winter buds or Stars
,, 8	*Water - action — deepening	Circulation of water	Clouds and rainbow	Parrot or Pigeon
,, 15	*Widening ..	Velocity of flow and slope	Our arms and legs	Horse
,, 22	Striking grade ..	A creek or stream	Clothing of animals	Violet
,, 29	Pupae & Cocoons	Water - worn stones, Sheep or Goat	Almond blossom; Coal or Frog's eggs	How animals clean themselves
Aug. 5	Tongues of animals	Heath or Tails of animals	Dog or Sky and stars	Jonquil
,, 12	Arum or Crocus	Carrot or Snowdrop	Sunshine or Sand, clay and soil	Orange
,, 19	Wood - sorrel, or Turnip	Growing wheat plant	Pinetree and cone	Pea plant
,, 26	Primrose or Moss	Early Nancy or Daffodil	Play of animals or Buttercup	Growing onion or Early Nancy
Sept. 2	Poplar-tree or Pittosporum	Willow or Elm	Wattle blossom ..	Bursting buds or Snail
,, 9	*Pumpkin, French Bean, Germinations	Daisy or Wild flowers	Potato & growth	Signs of spring or Shapes of leaves
,, 16	Gum sawfly larvae, Chickweed, or Shepherd's purse	Grass caterpillar or Woolly bear	Appletree in Spring	Oak tree or Wild flowers
,, 23	Lilac or Orchid..	Peach tree buds or Housefly	Tadpole ..	Gorse or Cherry blossom or Water babies
Oct. 7	Movements of birds	Cockatoo or Myna or Fantail	Canary or Feather	Egg or Movement of bird
,, 14	Color of birds ..	Swallow ..	Songs and calls of birds	Hen and Chickens
,, 21	Education of young or Cuckoos or Pigeon	How birds clean themselves	Duck or goose	Birds' nests
,, 28	Onion grass or Bluebell	Honeysuckle or Wall flower	Broad bean flower	Silkworm eggs and young
Nov. 4	Capeweed or Convolvulus	Mallow plant or Sweet pea plant	Carnation or Poppy	Pea plant and flowers
,, 11	Wasps' nests or Broom	Columbine or Wandering Jew	Bee or Grasses ..	Cape weed
,, 18	Caddis larvae or Cornflower	Pond snails or Pond animals	Dolichos or Geranium	Pea fruit and seeds
,, 25	Whirligig beetle or Clover	Water fern or Pond plants	Baby seeds and fruits	White (Christmas) lily
Dec. 2	*Grass seeds and burrs or Loquat	Wheat plant or Periwinkle	Broad bean fruit and seed	Silkworm
,, 9	*Pumpkin & French bean plants	Wind carried seeds or Soldier bug	Scents of flowers or Sandpatch	Cherry
,, 16	Cranesbill, Silkworm or Mussel	Pansy, Butterfly or Sand hoppers	Frog or Sea animals	Flying seeds
,, 23	Pumpkin flower, Limpets & mail fish.	Buffalo grass or Sea anemone	Apricot, Gooseberry or Broom plant	Silkworm cocoon and moth

‡ L.H. = life history.

Some subjects cannot be arranged for a definite date. Knowing several weeks ahead that a study of a thunderstorm or a flight of swifts is desired, advantage would be taken of such phenomena and the lesson given when the subject is under notice.

Announce at least two weekly lessons in advance; then, if material for the first is scarce, the second can be substituted. No rigid scheme is possible. Dry weather may render the study of Aphis, scale, and lady-bird useless in March, or of mosquito useless in April. These must then be left for a favorable time. An animal not on the list may appear in numbers; that is, the proper subject for study. Again, persons with special knowledge and interest, will take many studies in a special branch, while others will give only one in that branch. Take what Nature brings, and do not, as a general rule, give the same lesson to the same pupils a second time.

The teacher giving a fresh lesson each week will not, as a rule, write out elaborate lesson notes. Still a grade teacher will take about eighty per cent. of the same course each successive year with different children, and should for her own information keep brief notes.

The other twenty per cent. of the topics treated will vary with the season and the relative abundance of material. In time, grade teachers will accumulate notes and suggestions on the work of their grade.

D.—The Daily Talk.

Educationists writing on nature-study invariably recommend a daily study. The value of a daily period is fully recognized, but it is limited here to five minutes and is *not* a short lesson. It is the children's time for reporting something seen since the previous morning, passing in specimens, or asking questions. It is concerned with the private observations of the child when he is free from the direction of the teacher.. The daily talk—the cream of our nature-study work—cannot be a success unless fresh ideas are steadily supplied to the child. The teacher acts as chairman and allows full freedom. If the work cannot be completed in five minutes, that is the best evidence of its success. If it can be completed, probably something is wrong. Why should it be completed? If each child has something to report, the object is gained. Children of ten and upwards should, where practicable, keep a private observation book. Always, however, have some oral reports. Don't be ambitious and expect elaborate observations. Don't drive children by questioning to add details that are not true. Don't tell what children can be led to discover for themselves, for it is a crime to deprive the children of the honor and pleasure of making a discovery.

The weekly lesson provides ideas and trains the child to see; the daily talk applies the ideas, and exercises and develops the power of seeing and enjoying, thus laying the foundations of a life-long observing habit. Guard in the morning talk against encroachment on future lessons. The danger of this encroachment is the chief drawback to the morning talk. If an observation connected with a coming lesson is reported, make it a query, and defer dealing with it until the period for that subject. It is important that the power of seeing and enjoying quite independently of the teacher is being developed. Self-help is the aim.

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The numbers are all in strict consecutive order. Figures in italics refer to the plates or the legends thereunder, in Roman to the letterpress.

[1]Numbers in italics refer to the plates; in Roman to the letterpress.

[2]For "21,3,*6*" and "55-7," read pages 21, 23, *26* (plate), 55, 56, and 57.